AD-784 940

EXTENDED ARRAY EVALUATION PROGRAM. SPECIAL REPORT NUMBER 12. CONTINUED EVALUATION OF THE NORWEGIAN LONG-PERIOD SEISMIC ARRAY - FINAL REPORT

Philip R. Laun, et al

Texas Instruments, Incorporated

Prepared for:

Advanced Research Projects Agency
Air Force Technical Applications Center

3 December 1973

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ALEX(01)-STR-73-12

EVALUATION OF THE NORWEGIAN LONG-PERIOD SEISMIC ARRAY - FINAL REPORT

SPECIAL REPORT NO. 12

EXTENDED ARRAY EVALUATION PROGRAM

Prepared by

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AIR FORCE TECHNICAL APPLICATIONS CENTER
AFTAC Project No. VELA T/2705/B/ASD
Alexandria, Virginia 22314

Sponsored by

ADVANCED RESEARCH PROJECTS AGENCY
Nuclear Monitoring Research Office
ARPA Program Code No. 2F10
ARPA Order No. 1714

3 December 1973

Acknowledgment: This research was supported by the Advanced Research Projects Agency, Nuclear Monitoring Research Office under Project VELA-UNIFORM, and accomplished under the technical direction of the Air Force Technical Applications Center under Contract No. F33657-72-C-0725.

ABSTRACT

This report describes the final results of the continued evaluation of the Norwegian Long-Period Seismic Array (NORSAR) by Texas Instruments Incorporated at the Seismic Data Analysis Center over the period 1 April 1973 to 30 September 1973.

The major areas of study were:

- Noise analysis
- Array processing performance
- Effectiveness of matched filters
- Surface wave detection capability
- Performance of standard surface wave discriminants

A total of 133 Eurasian events and 36 noise samples were processed and analyzed during this period. The results were combined with earlier data, when applicable, in order to maximize the data base.

TABLE OF CONTENTS

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER AD-784 940
4. TITLE (and Subtitle) EVALUATION OF THE NORWEGIAN LONG-PERIOD SEISMIC ARRAY - FINAL REPORT		5. TYPE OF REPORT & PERIOD COVERED Special
		6. PERFORMING ORG. REPORT NUMBER ALEX(01)-STR-73-12
7. AUTHOR(s) Philip R. Laun, Wen-Wu Shen, and William H. Swindell		8. CONTRACT OR GRANT NUMBER(s) F33657-72-C-0725
9. PERFORMING ORGANIZATION NAME AND ADDRESS Texas Instruments Incorporated Equipment Group Dallas, Texas 75222		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS VELA T/2705/B/ASD
11. CONTROLLING OFFICE NAME AND ADDRESS Advanced Research Projects Agency Nuclear Monitoring Research Office Arlington, Virginia 22209		12. REPORT DATE 3 December 1973
		13. NUMBER OF PAGES 134
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Air Force Technical Applications Center VELA Seismological Center Alexandria, Virginia 22314		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

APPROVED FOR PUBLIC RELEASE, DISTRIBUTION UNLIMITED

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

ARPA Order No. 1714

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Norwegian Seismic Array (NORSAR) Evaluation
Seismic noise analysis
Chirp matched filter
Seismic event detection
Seismic event discrimination

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TABLE OF CONTENTS
(continued)

LIST OF FIGURES

LIST OF FIGURES
(continued)

LIST OF FIGURES
(continued)

LIST OF TABLES

SECTION I

INTRODUCTION

This report presents the cumulative and final results of a study of the Long Period Norwegian Seismic Array (NORSAR). The study began on April 1971 for the purpose of evaluating:

- The array detection capability for Eurasian events
- The performance of various discriminants at NORSAR for Eurasian events
- Methods of sustaining or enhancing these capabilities.

These three objectives were achieved by the following studies:

- Noise analysis
- Signal analysis
- Array processing effectiveness
- Matched filtering performance
- Detection threshold estimation
- Behavior of standard discriminants.

The study consists of three reports: Texas Instruments Special Report No. 5, 1972; Texas Instruments Special Report No. 7, 1973; and this report which is the third and final report.

The noise analysis is covered in some detail in both Special Report No. 5 and No. 7, however, some additional data are presented here.

The signal analysis for the full array was completed in Special Report No. 5 and results for the partial array are presented here.

The array processing performance study is continued throughout the three reports. The first report was concerned with the feasibility of routine MCF processing, noise stationarity, and signal degradation by the beamsteer processor. The second report, with additional data, continued the comparison of MCF and beamsteer performance for both the full array and for various subarrays, investigated the azimuthal dependence of array gains, and compared signal-to-noise ratio (SNR) improvements of the MCF and beamsteer processors for several seismic events. This report contains additional partial array MCF and beamsteer processing and a further investigation of the effectiveness of MCF's designed from noise which occurs many days before or after the time of application.

The matched filtering performance, detection threshold estimation, and the behavior of standard discriminants studies, which depend upon a large ensemble of events for reliable estimates have been reported in preliminary fashion in the first two reports. In this report, these earlier data have been combined with 33 additional events from August and November 1972 and the final results are presented.

The data used in this report are discussed in Section II. Sections III through VII contain the various studies listed above. Section VIII summarizes the results, presents conclusions and lists areas for further study. Appendix A contains the list of all events used in the evaluation, Appendix B discusses the events which have been dropped from the data base, Appendix C contains a list of the noise samples used, and Appendix D contains some observations on linear group velocity chirp filter design.

The long period NORSAR is an array of 22 seismometer sites spread over a circular area approximately 100 km in diameter, and is located north of Oslo, Norway. Each site consists of three orthogonal seismometers

(vertical, north-south, east-west) with a response centered at 25 seconds. A diagram of the array is shown in Figure I-1.

Long-period NORSAR data is received at the Seismic Data Analysis Center (SDAC) from Norway by a communication system called the Trans-Atlantic Link (TAL). These data are recorded on magnetic tape, along with ALPA and LASA long-period data, and saved for future analysis. The analysis was performed at the SDAC using an off-line array evaluation software package developed by Texas Instruments under Contract No. F33657-69-C-1063.

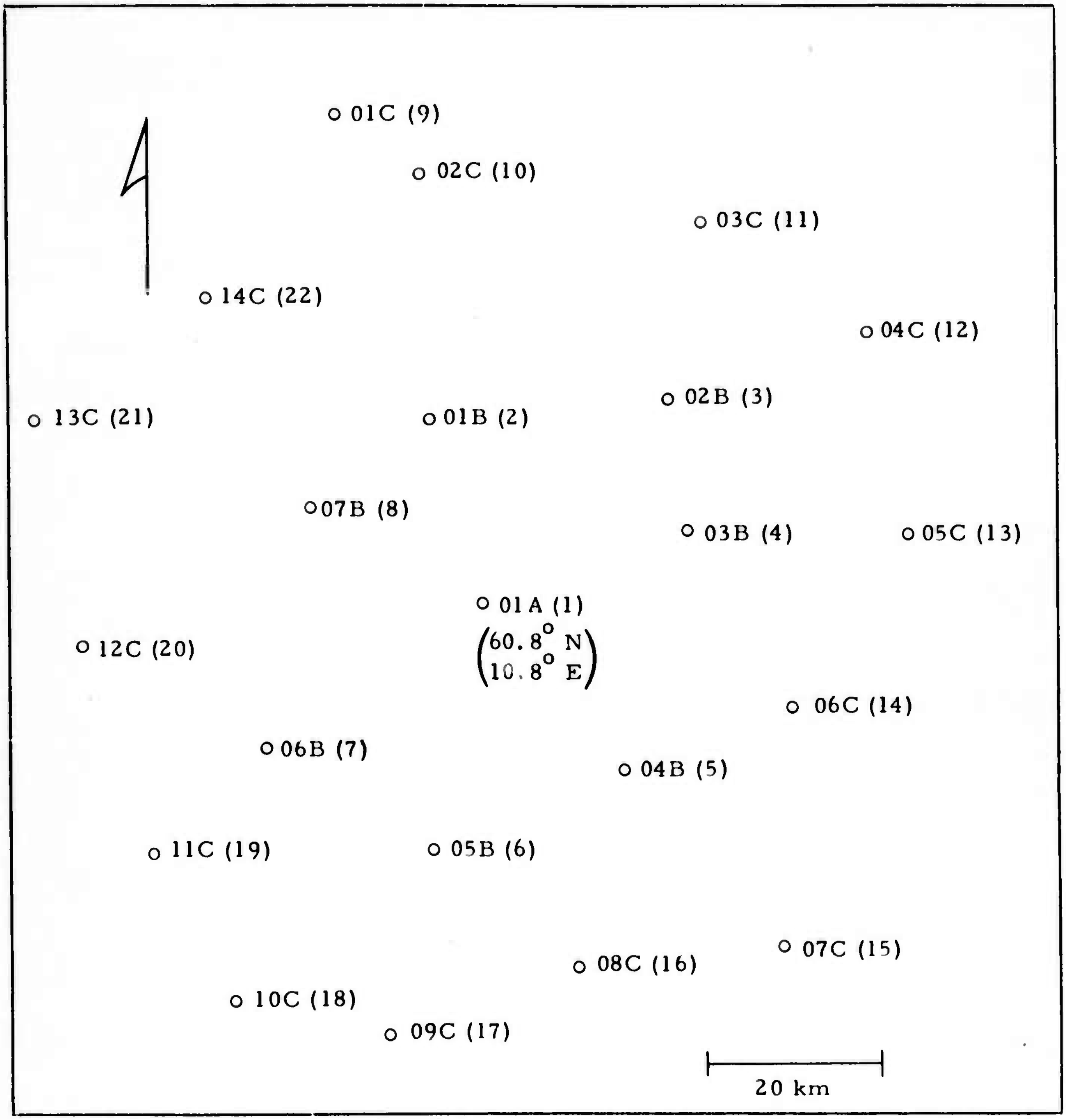


FIGURE I-1

SITE DIAGRAM OF THE NORSAR LONG-PERIOD ARRAY

SECTION II

DATA BASE

The data used in this report consist of the signals and the noise samples analyzed in the two previous reports, Special Reports No. 5 and No. 7, plus an additional 36 noise samples from about two to seven hours long recorded from August 1972 to March 1973, 133 events from August and November 1972, and all 1973 presumed explosions through August 1973.

Appendix A contains the total list of events processed, and Appendix C contains the list of noise samples edited along with the various parameters associated with them. A histogram of the bodywave magnitude (m_b) distribution of the events processed is given in Figure II-1.

With a few exceptions, only those events originating in Europe and Asia were selected. Since one of the primary objectives of the analysis was to obtain good estimates of detection threshold, many events were needed at the lower magnitudes with $m_b \leq 4.5$. These events were obtained mostly from the LASA and NORSAR bulletins with the remainder obtained from the PDE bulletin. The various event information sources are detailed in Appendix A.

The events in Appendix A are 515 events successfully processed from a list of 839 events considered. The events not processed were rejected for the following reasons:

Lack of data or gaps on tape	175
Parity errors, spikes, other tape problems	17
Mislocated events	4
Interfering events	103
Events later shown to be deep (>50 km)	25
	324

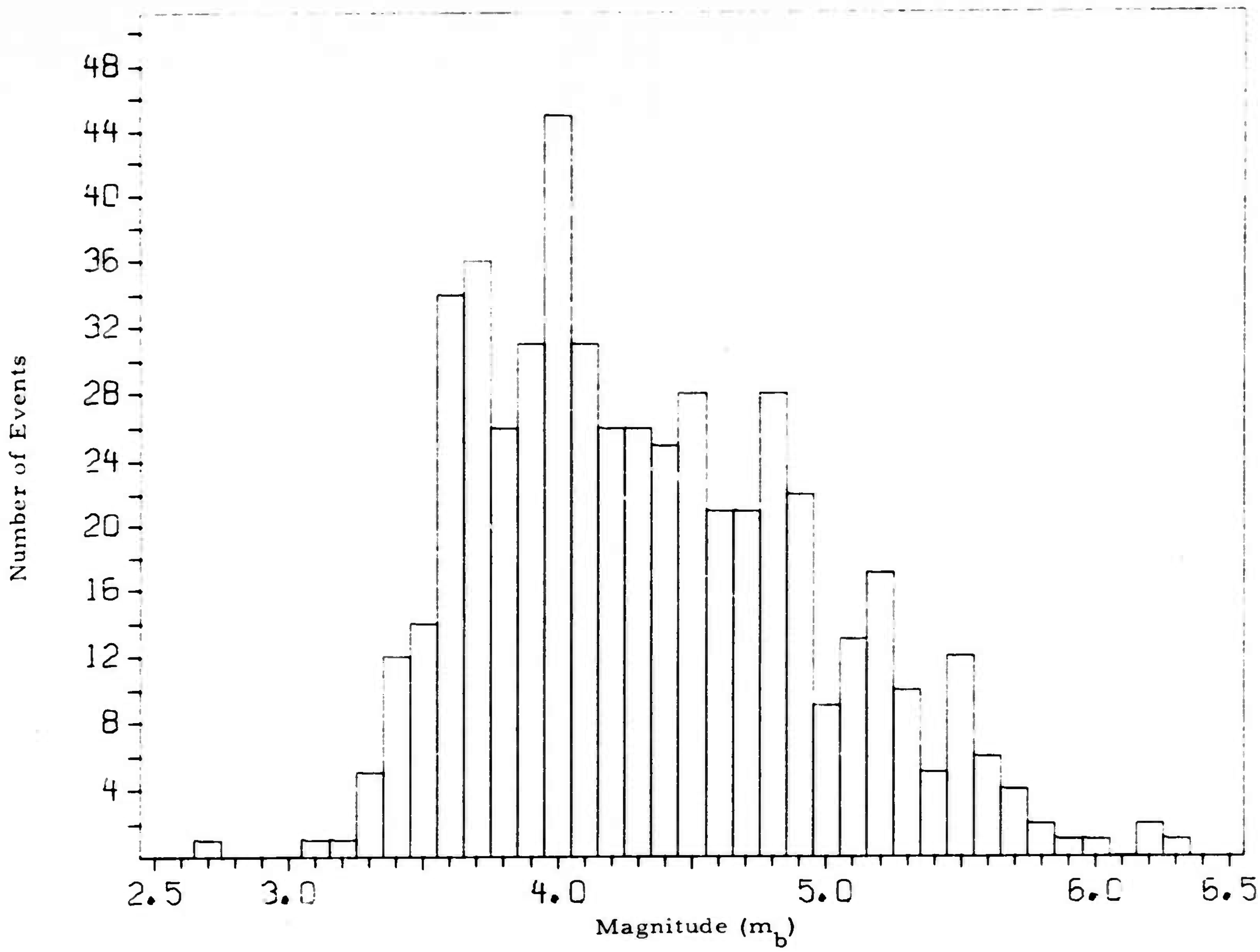


FIGURE II-1

m_b DISTRIBUTION OF EVENTS ANALYZED AT THE NORSAR LONG PERIOD ARRAY APRIL 1971 - AUGUST 1973

Thus, aside from the technical difficulties of recording which account for 21% of the total events, one can expect a certain loss of signals due to interfering events (17% in this case).

The basic signal processing consisted of editing the event including at least 1200 seconds of noise preceding the P-wave arrival, rotating the components to vertical, transverse and radial, and beam-steering in the source direction using 3.5 km/sec for the vertical and radial and 4.0 km/sec for the transverse. Processing of the 1971 events was done using three different passbands to determine which was the most suitable. On the basis of this study, a 17 - 40 second band (0.025-0.059 Hz) was decided upon and used for the 1972 and 1973 data. This particular band was not used for the 1971 events, so 1971 results from the 17 - 50 second (0.020-0.059 Hz) band were used.

SECTION III

NOISE ANALYSIS

A. INTRODUCTION

The noise analysis presented in this section is an extension of the noise field study performed in the preceding years (Special Report No. 5, 1972; Special Report No. 7, 1973). The objective of this analysis is to characterize the noise field at NORSAR to improve signal enhancement and detection performance.

The long-period noise investigation includes:

- Time variability
- Noise directionality
- Spatial coherence.

B. DATA BASE

In addition to the noise samples of Special Report No. 5 and No. 7, a total of 36 new noise samples were edited for this report covering the period from August 1972 to March 1973. The duration of these samples ranged from about two to seven hours with an average length of about four hours. A list of the complete noise ensemble used in this study is in Appendix C.

The data were sampled at two-second intervals and were recorded in 256-second segments. After quality checking the data, cross-power matrices were then computed at 64 frequencies from 0.0 to 0.25 Hz for each noise sample. Quality checks included plots of the vertical components of

three or four sites to check for unreported surface waves, and inspection of the individual segment powers and the site auto-power spectra for unusual values.

The average number of sites available was nineteen, an increase of four from last year. Figure III-1 shows a histogram of the number of times a site was deleted versus the site number.

C. TIME VARIABILITY OF THE AMBIENT NOISE LEVELS

The comparison of earlier noise spectra with the spectra of the latest data showed that the vertical and horizontal components of the noise field have continued to show the same spectral behavior. In addition the horizontals contained both Love and Rayleigh wave energy and were slightly less coherent than the verticals (Special Report No. 5), so for these reasons, the study was done only of the vertical component.

In general, the noise spectra showed two microseismic peaks: a lower one at about 0.06 Hz (16 second period) and an upper one at about 0.12 Hz (6 - 8 second period). The former occurs near or within the signal processing band (0.025 to 0.059 Hz or 17 to 40 seconds) while the latter is far beyond it. For the purpose of signal processing and detection, the noise in the signal band is our primary concern. Figure III-2 shows the frequency of the lower microseismic peak for each sample. The peak frequency ranged from 0.051 to 0.083 Hz (about 12 - 20 seconds) with perhaps a slight tendency to be nearer the lower frequency range in the winter than in the summer. This lowering of the peak frequency to the edge of the signal processing band during winter, coupled with an increase in noise level and coherence (discussed below) suggests that the use of MCF processing may be advantageous during the winter months. This is discussed further in Section IV.

Monitoring the seasonal changes in noise levels was continued from Special Report No. 7. Figure III-3 shows the average single site RMS level

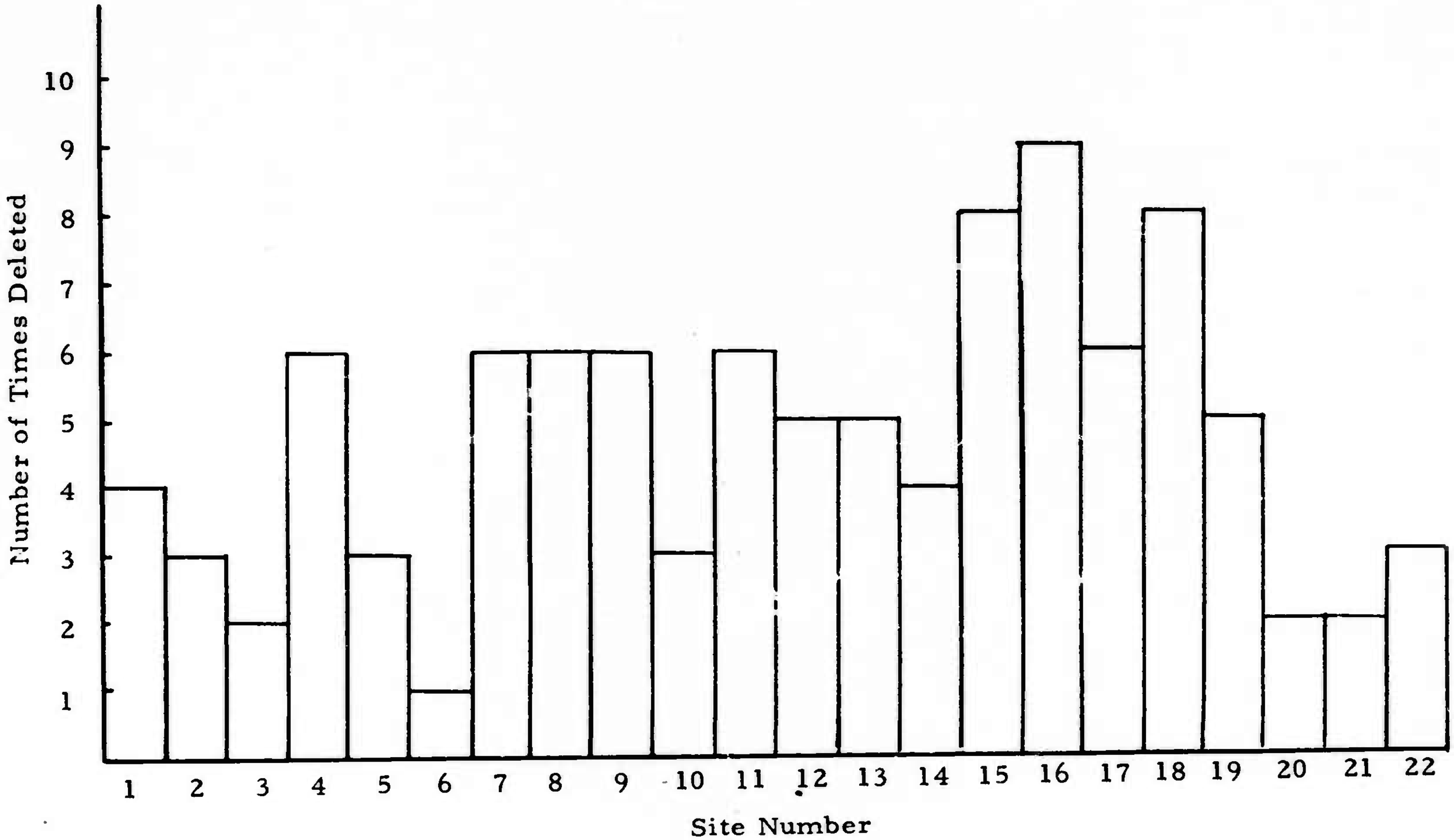


FIGURE III-1

HISTOGRAM OF SITE AVAILABILITY
(36 NOISE SAMPLES)

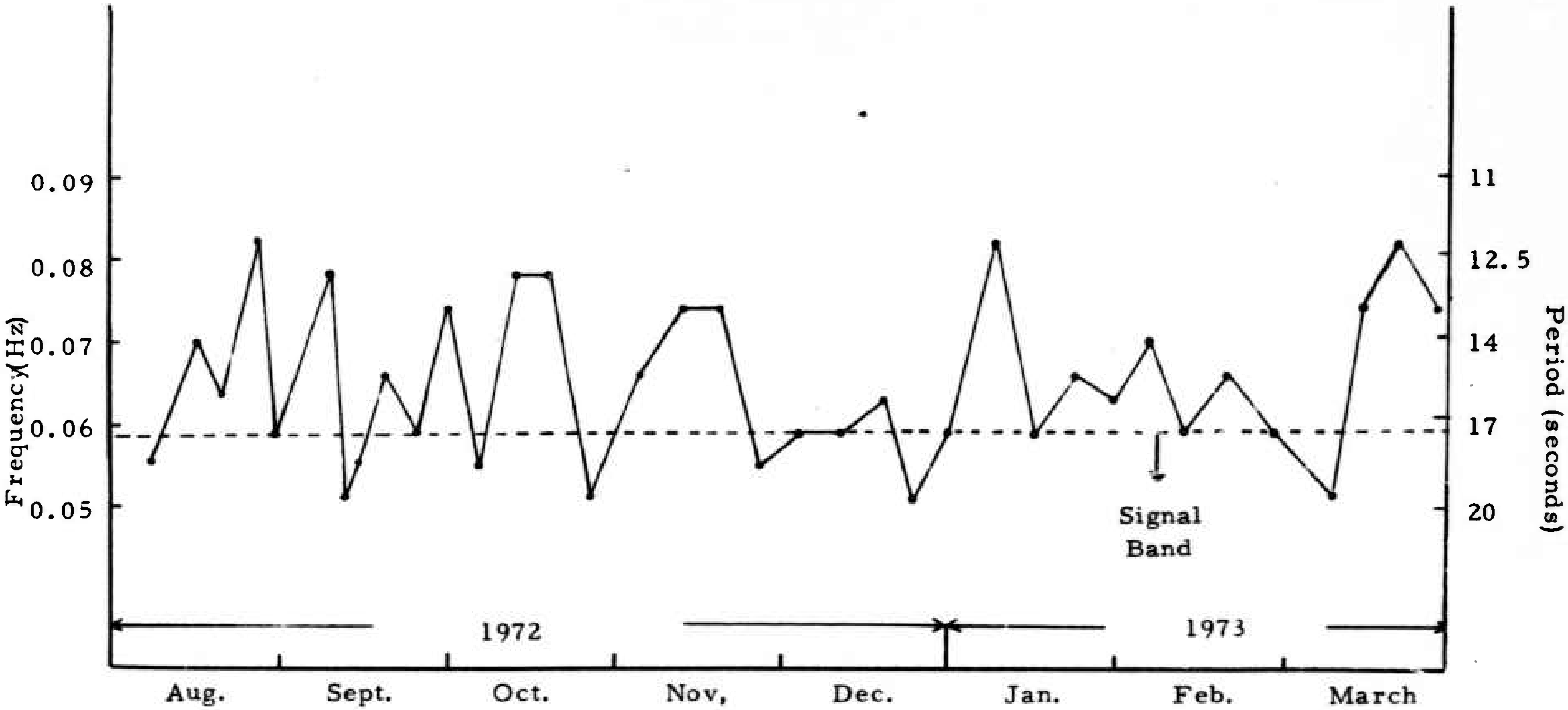


FIGURE III-2

THE FREQUENCY OF LOWER MICROSEISMIC
PEAK OF NOISE SAMPLES

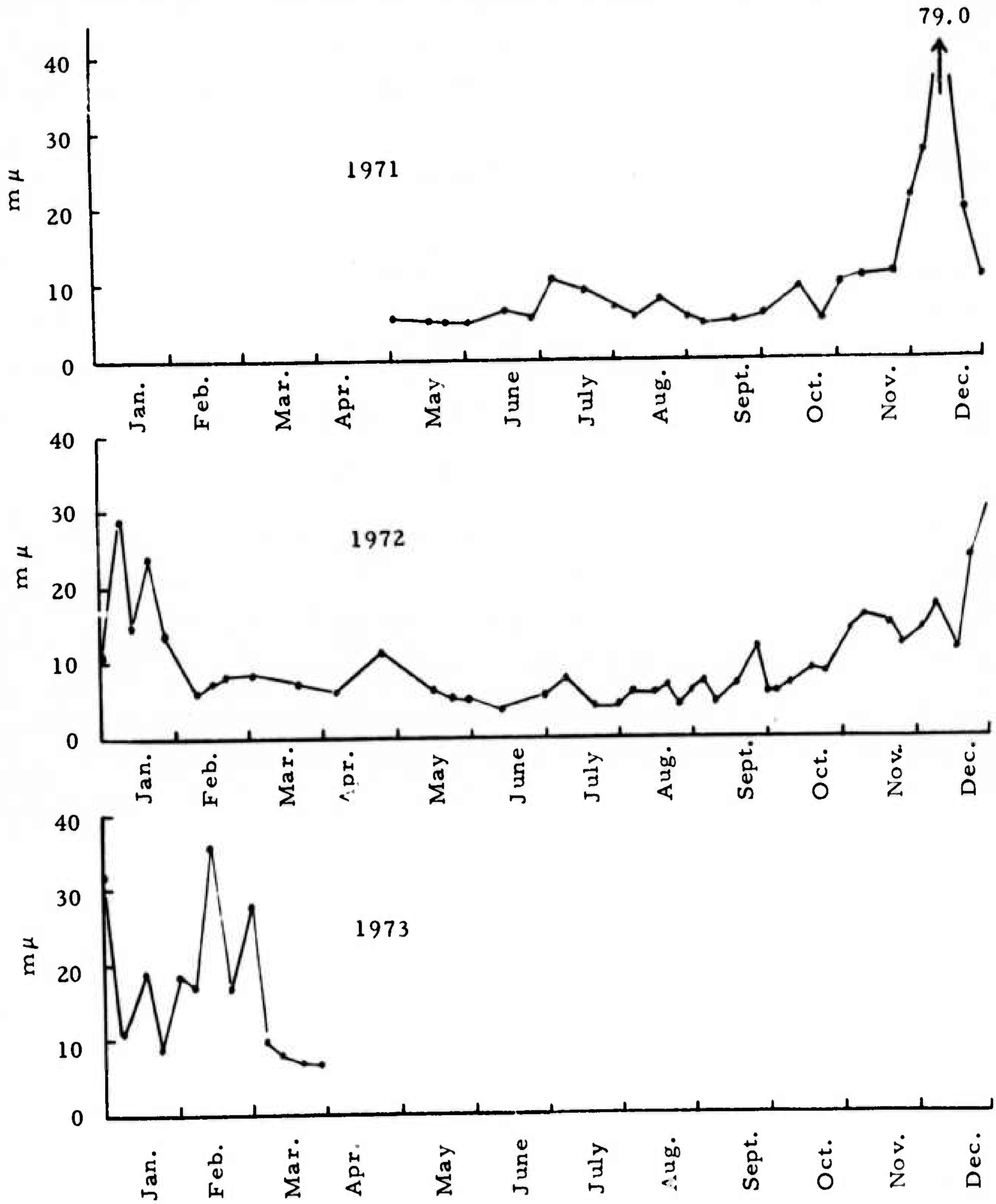


FIGURE III-3

AVERAGE SITE RMS LEVEL OF NOISE
(20-40 SECONDS)

(20 - 40 second period band) of each noise sample versus time. This figure includes the entire noise ensemble from May 1971 to March 1973. These data confirm the seasonal noise trends of the 20 to 40 second period band at NORSAR as discussed in Special Report No. 7. From early spring, about February or March, NORSAR has low (7mμ RMS), mildly fluctuating noise levels until late fall. Beginning in October, the noise starts to rise rapidly and erratically to the mid-winter months of December to February, during which the noise level is highly variable and probably dependent on the severity of the North Atlantic weather. In February or March the noise level rapidly assumes its summer level when the severe winter storms apparently abate.

In summary, the conclusions of this study are:

- The frequency of the lower microseismic peak lies in the range of 0.05-0.08 Hz (20 - 12 seconds) with a strong tendency of dropping to 0.06 Hz (17 seconds) in winter.
- The 20 to 40 second RMS noise level was about 6 to 7 mμ in the summer, about 14 mμ in late autumn and early winter, with erratic fluctuations in the late winter up to a maximum. The maximum observed level of 79 mμ would increase the detection threshold from summer to winter about 1.2 Ms units.

D. NOISE DIRECTIONALITY

The directionality of the noise was investigated by means of high resolution f-k spectra computed for the vertical component of each noise sample at the frequency of the lower microseismic peak.

Figure III-4 shows primary noise directions of each sample. The solid dots indicate the azimuths of maximum power density at a velocity of 3.5 km/sec for the corresponding frequencies shown in Figure III-2. The range

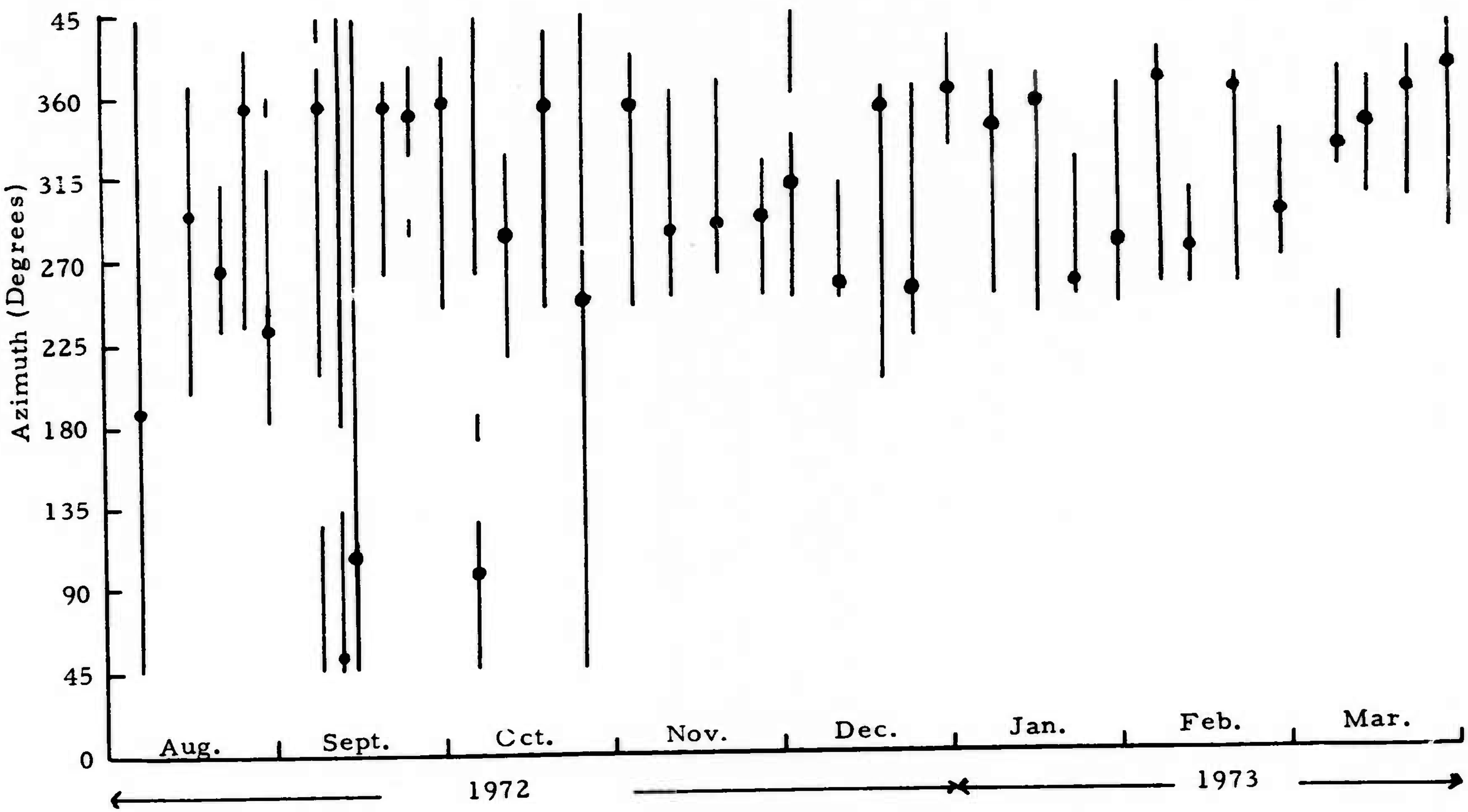


FIGURE III-4

NOISE SOURCE AZIMUTHS

of azimuths where the power was within 6 dB of the peak power is shown by vertical straight lines for each noise sample. Figure III-4 shows that the noise power was generally isotropic in the summer, but was primarily from the north to northwest in the winter with azimuths near 0^o, 250^o, and 280^o occurring most often. The noise directions of the last four noise samples (in March 1973) were typical of winter noise even though the noise levels had dropped back to summer values. This shows more evidence of the low correlation between noise level and direction observed previously.

E. SPATIAL COHERENCE

Multichannel coherences were computed for the 7 August, 4 November, 1972 and 8 January 1973 noise samples (Figures III-5, III-6 and III-7). Because of the interest in small array (≤ 8 sites) performance, two cases of multichannel coherence were computed: first, site 1 was predicted from all the other sites in the array, and second, site 1 was predicted from only the inner-ring sites.

For all three samples, the coherences of both the inner ring and the full array are nearly the same although the inner ring coherence is slightly less due to the fewer number of sites used. These figures also illustrate some of the problems involved in MCF design. Coherence plots in Special Report No. 5 of summer and winter data indicated that the highest coherences were at the lower microseismic peak, however, Figure III-5 shows that the noise from 7 August 1972 has its highest coherence at 0.08 Hz when the microseismic peak from Figure III-2 is at 0.055 Hz. At this latter frequency, the coherence is very low so that MCF processing would not be worthwhile. Figure III-6, for 4 November 1972, shows high coherences within the signal band but that the peak power is at 0.066 Hz, outside the signal band. These are indications of potentially

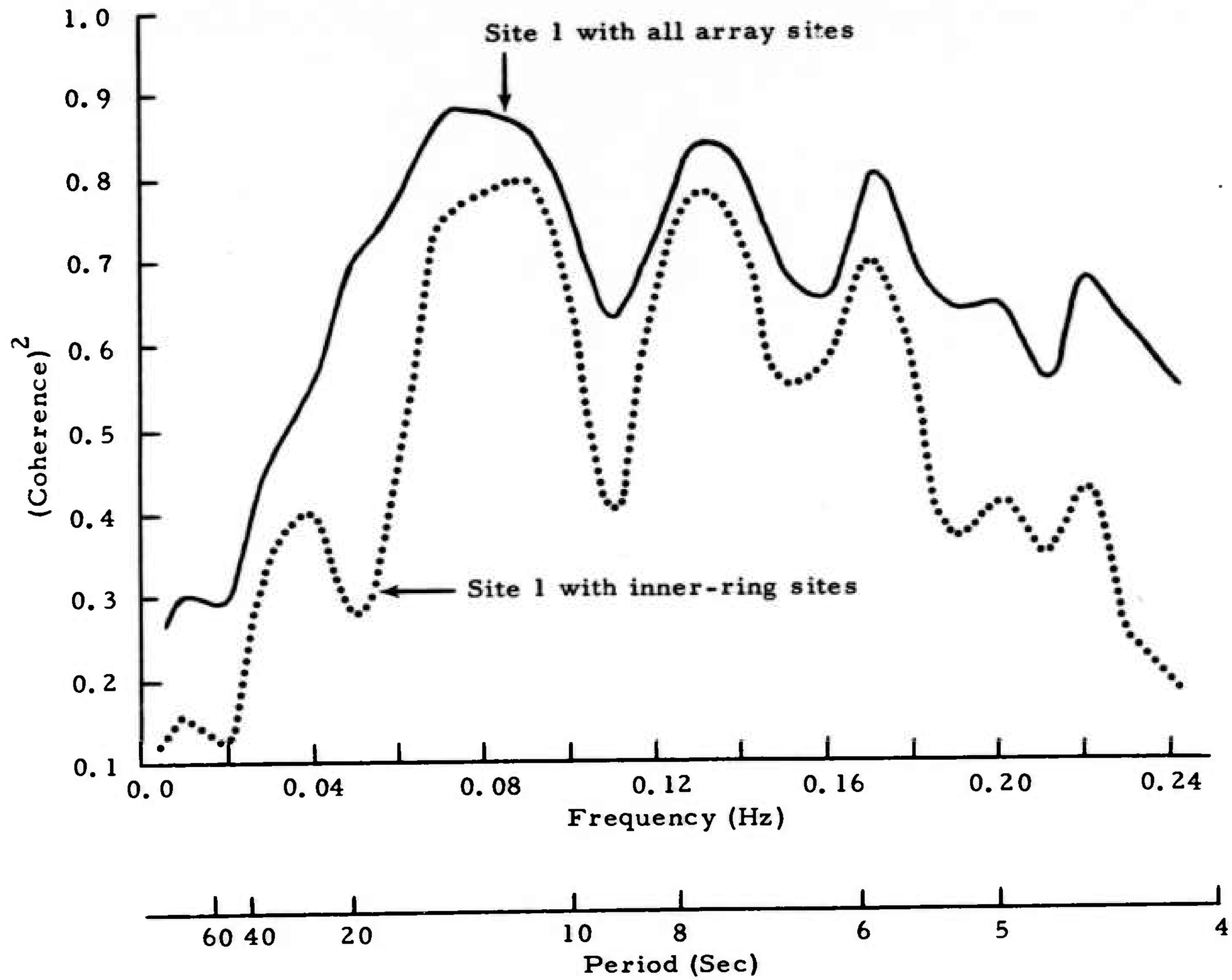


FIGURE III-5

MULTICHANNEL COHERENCE OF THE 7 AUGUST 1972 NOISE SAMPLE

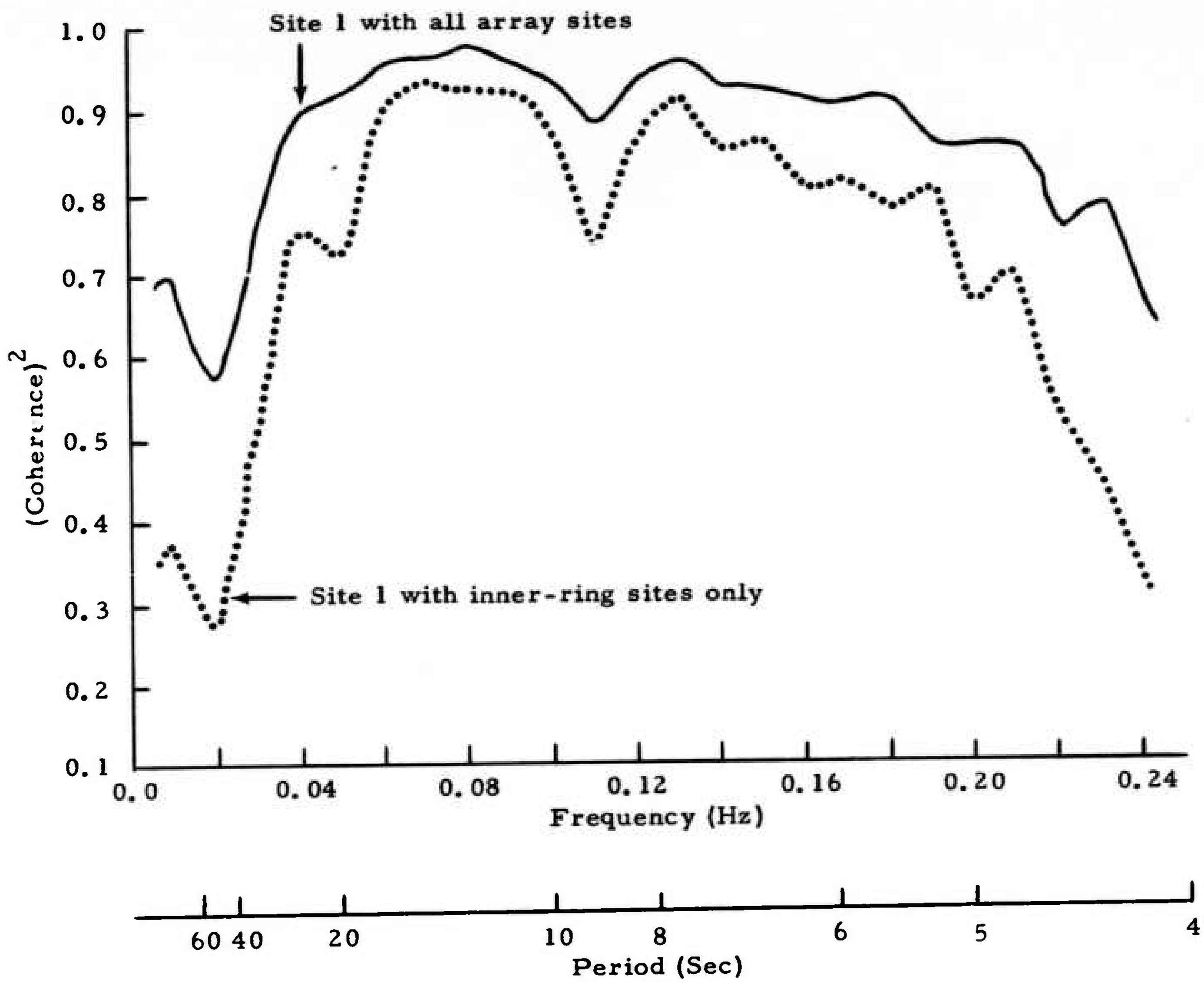


FIGURE III-6

MULTICHANNEL COHERENCE OF THE 4 NOVEMBER 1972 NOISE SAMPLE

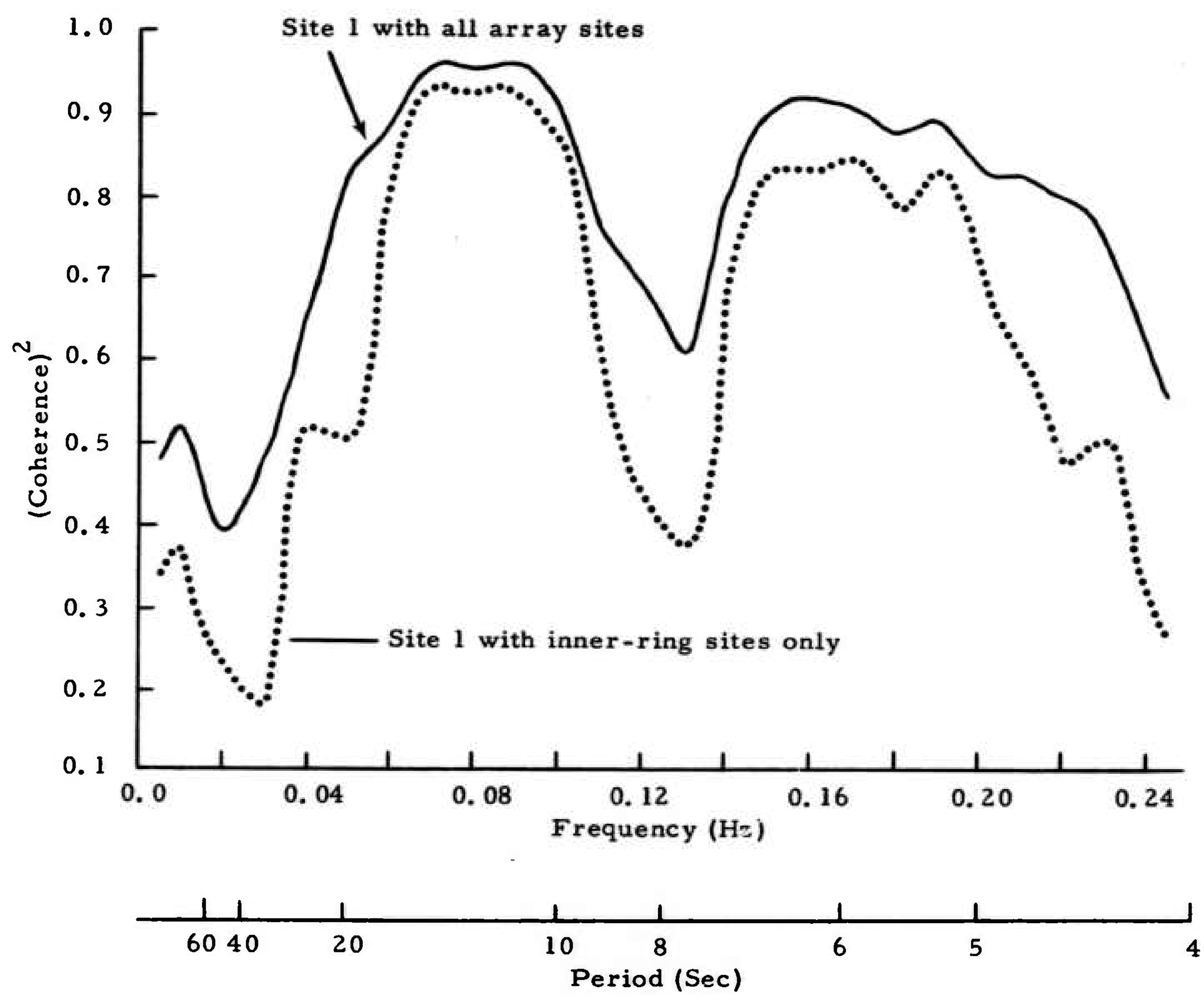


FIGURE III-7

MULTICHANNEL COHERENCE OF THE 8 JANUARY 1973 NOISE SAMPLE

high MCF effectiveness. The 8 January 1973 sample, Figure III-7, has both microseismic peak power and high coherencies outside the signal band. Even though this noise sample is typical winter noise, the low signal band coherence indicates that an MCF would probably be ineffective. As will be shown in Section IV, the predictions of MCF effectiveness for these noise samples are borne out.

F. CONCLUDING REMARK

The thirty-six long duration noise samples, covering the periods from summer 1972 through early spring 1973, have been found to have time variability, and directionality consistent with previous results, therefore, their major characteristics can be considered well-defined. The coherences of the noise is not as well defined, but the coincidences of the microseismic peak power and maximum coherence in the winter gives strong evidence of discrete noise generating sources. MCF effectiveness becomes a function of the position of the microseismic peak in relation to the signal processing band. In the summer the peak power often occurs in the signal band but the noise is largely incoherent and isotropic so that MCF processing may not be justified.

SECTION IV

ARRAY PROCESSING PERFORMANCE

A. INTRODUCTION

The principal objectives in this extension of the NORSAR array processing performance evaluation were:

- Continued exploration of the feasibility of routinely designing and applying multichannel filters (MCF's).
- Comparison of the effective noise rejection and signal degradation of the full NORSAR array and a reduced array consisting of only the inner ring sites.

These objectives were accomplished by:

- Estimating the noise rejection achieved by the MCF and beamsteer (BS) processors for the full array and the reduced array.
- Measuring the signal degradation caused by the MCF and BS processors for both arrays.
- MCF processing of signals using only one noise sample for MCF design.

B. DATA BASE

Twenty- three samples of noise data for the period from 7 August 1972 to 20 February 1973 were used for MCF design. Both the MCF and beamsteer processor were then applied to two portions of a noise sample called on-

design noise and off-design noise. The former was in the MCF design gate and the latter outside of the design gate. Each portion was 4096 seconds long.

Twelve events from the 1972 summer event ensemble were used for signal beamforming loss and noise reduction measurements for the full NORSAR array and the reduced array. Similar measurements were made on seven August 1972 events processed by an MCF beamformer.

Using the 19,200-second data from the 7 August 1972 noise sample, MCF's were designed and applied to the noise preceding 31 events occurring between 3 August and 18 August 1972. The purpose was to compare the noise reduction achieved by MCF and BS processors on data increasingly displaced in time from the MCF design interval. Relative signal-to-noise ratios were computed on the 19 events having moderate signal-to-noise ratios on the single site.

C. MCF AND BEAMSTEER NOISE REJECTION.

The MCF's were computed for only the vertical component of the data, using the design parameters of Special Report No. 7:

- Dispersive signal model oriented to a beam direction of 90°
- Signal-to-noise ratio equal to four at all frequencies
- Two percent white noise added to the data
- Frequency domain design by transforming, cross-multiplying and stacking 256-second segments at all frequencies 0.00-0.246 Hz. The data were not hanned

On the average, 20 sites were available for the full array and seven sites for the reduced array.

TABLE IV-1

IMPROVEMENT IN NOISE REJECTION BY MCF PROCESSOR FOR THE FULL AND REDUCED NORSAR ARRAY.
(PAGE 1 OF 2)

	Array Size	No. of Sites	MCF Over BS Noise Rejection (dB) For Various Passbands Shown in H_z					
			On-Design Noise			Off-Design Noise		
			0.025 to 0.050	0.025 to 0.059	0.020 to 0.100	0.025 to 0.050	0.025 to 0.059	0.020 to 0.100
8/07	Full	22	2.2	2.7	2.5	---	---	---
	Reduced	8	0.8	1.2	1.7	---	---	---
8/20	Full	21	2.4	3.8	8.3	0.4	3.1	8.5
	Reduced	8	3.0	6.2	10.6	3.4	7.0	10.9
8/24	Full	17	1.6	2.3	4.1	0.5	0.5	1.5
	Reduced	5	1.7	1.8	2.8	0.4	0.5	1.0
9/9	Full	21	1.2	1.7	5.0	(-1.9)	(-1.2)	2.2
	Reduced	8	0.7	1.0	4.7	1.9	1.4	4.2
9/12	Full	17	4.0	5.0	4.4	1.4	1.4	1.3
	Reduced	8	2.5	2.8	2.8	1.0	1.5	1.2
9/19	Full	20	2.7	2.3	5.5	(-1.9)	(-1.2)	2.8
	Reduced	7	(-0.2)	0.3	3.9	2.0	1.4	4.9
9/24	Full	19	3.0	2.1	4.8	(-0.1)	(-0.3)	2.9
	Reduced	7	1.3	5.6	8.8	5.3	8.6	9.2
10/1	Full	21	2.5	3.4	6.6	0.1	1.1	5.1
	Reduced	7	3.4	4.8	6.7	2.4	4.3	6.0
10/6	Full	20	1.4	1.7	1.9	(-1.2)	(-1.6)	(-1.3)
	Reduced	7	2.0	2.2	2.4	0.4	0.5	0.8
10/18	Full	13	3.5	1.6	4.5	1.1	1.1	2.3
	Reduced	6	5.1	3.0	4.5	3.0	2.3	3.0
10/27	Full	18	2.6	2.7	3.2	(-4.7)	(-3.1)	(-0.4)
	Reduced	7	2.5	2.4	3.1	1.3	1.7	3.3
11/4	Full	22	2.5	3.7	9.1	1.4	1.9	6.7
	Reduced	8	4.5	4.7	9.2	4.2	5.2	9.2

TABLE IV-1

IMPROVEMENT IN NOISE REJECTION BY MCF PROCESSOR
FOR THE FULL AND REDUCED NORSAR ARRAY.
(PAGE 2 OF 2)

Noise Sample Month/Day	Array	No. of Sites	MCF Over BS Noise Rejection (dB) For Various Passbands Shown in Hz					
			On-Design Noise			Off-Design Noise		
			0.025 to 0.050	0.025 to 0.059	0.020 to 0.100	0.025 to 0.050	0.025 to 0.059	0.020 to 0.100
11/12	Full	18	3.2	4.1	9.3	(-0.2)	0.5	5.4
	Reduced	7	3.8	4.4	8.4	2.3	2.5	4.8
11/20	Full	18	7.0	6.3	9.1	3.9	2.9	3.3
	Reduced	7	4.1	4.4	7.6	8.8	8.4	2.4
11/26	Full	20	5.2	5.8	6.2	3.1	3.4	4.2
	Reduced	7	4.7	5.4	5.9	3.1	5.6	5.8
12/10	Full	22	5.5	7.2	9.4	3.4	6.0	8.0
	Reduced	8	6.8	10.1	12.0	4.8	8.4	10.0
12/18	Full	20	3.5	4.0	6.1	---	---	---
	Reduced	8	3.5	3.7	6.6	4.1	4.4	6.6
12/25	Full	21	7.8	9.0	8.7	5.9	6.7	7.1
	Reduced	7	7.2	9.8	7.8	7.9	9.3	7.3
01/01	Full	19	5.4	7.1	7.3	1.1	3.0	5.4
	Reduced	7	6.2	7.0	6.4	4.3	4.8	5.8
01/08	Full	22	2.9	2.9	5.5	1.7	1.2	3.4
	Reduced	8	4.1	3.9	5.2	4.3	3.9	5.0
01/16	Full	22	3.9	7.5	9.3	0.3	2.2	4.1
	Reduced	8	2.0	4.2	7.8	(-0.1)	1.5	4.1
02/12	Full	19	5.5	9.5	11.8	3.4	7.4	9.8
	Reduced	5	6.9	8.4	8.7	5.0	7.2	7.8
02/20	Full	22	1.0	1.9	8.2	(-0.4)	0.0	3.7
	Reduced	8	2.3	3.6	9.1	0.9	1.4	6.2
Average	Full	(20)	3.5	4.3	6.7	0.8	1.7	4.1
	Reduced	(7)	3.4	2.6	6.4	3.2	4.2	5.5

Table IV-1 presents the relative MCF/BS noise rejection for the full and reduced arrays. Among the three passbands computed, the best improvement in noise rejection by the MCF generally was obtained in the wider band of 0.02-0.10 Hz. For the reduced array, the MCF was 4 dB more effective than the beamsteer processor in the signal processing band, however, this advantage dropped to less than 2 dB with the full array. Although the array gain of the full array is 4.5 dB (10 log (number of sites)) greater than the small array, the use of an MCF with the smaller array could reduce this site difference to less than 1 dB.

Previous analysis of only winter noise using the full array did not show much correlation between beam or single site noise level and improvement in array gain. With additional data covering the transition from summer to winter noise conditions. the winter rise in noise level is accompanied by a rise in MCF improvement although sample to sample correlation of level and improvement is still poor (Figure IV-1). However, for the reduced array, there is a strong correlation between the BS level and the relative MCF/BS noise rejection from sample to sample (Figure IV-2), particularly in the signal processing band.

Multichannel filter array gain improvement showed distinct changes related to the seasonal noise changes. For the full array, MCF-over-BS gains in the signal band fluctuated around the zero dB level before the 12 November noise sample, but showed significant improvements ranging from 0 to 7 dB with an average of about 4 dB in the winter. This implies that a decrease of 0.2 M_s units in the detection threshold could be achieved at NORSAR using an MCF processor in the winter. Even better gains were obtained for the reduced array; these ranged from 0 to 9 dB for both summer and winter at NORSAR with slightly less seasonal change being observed.

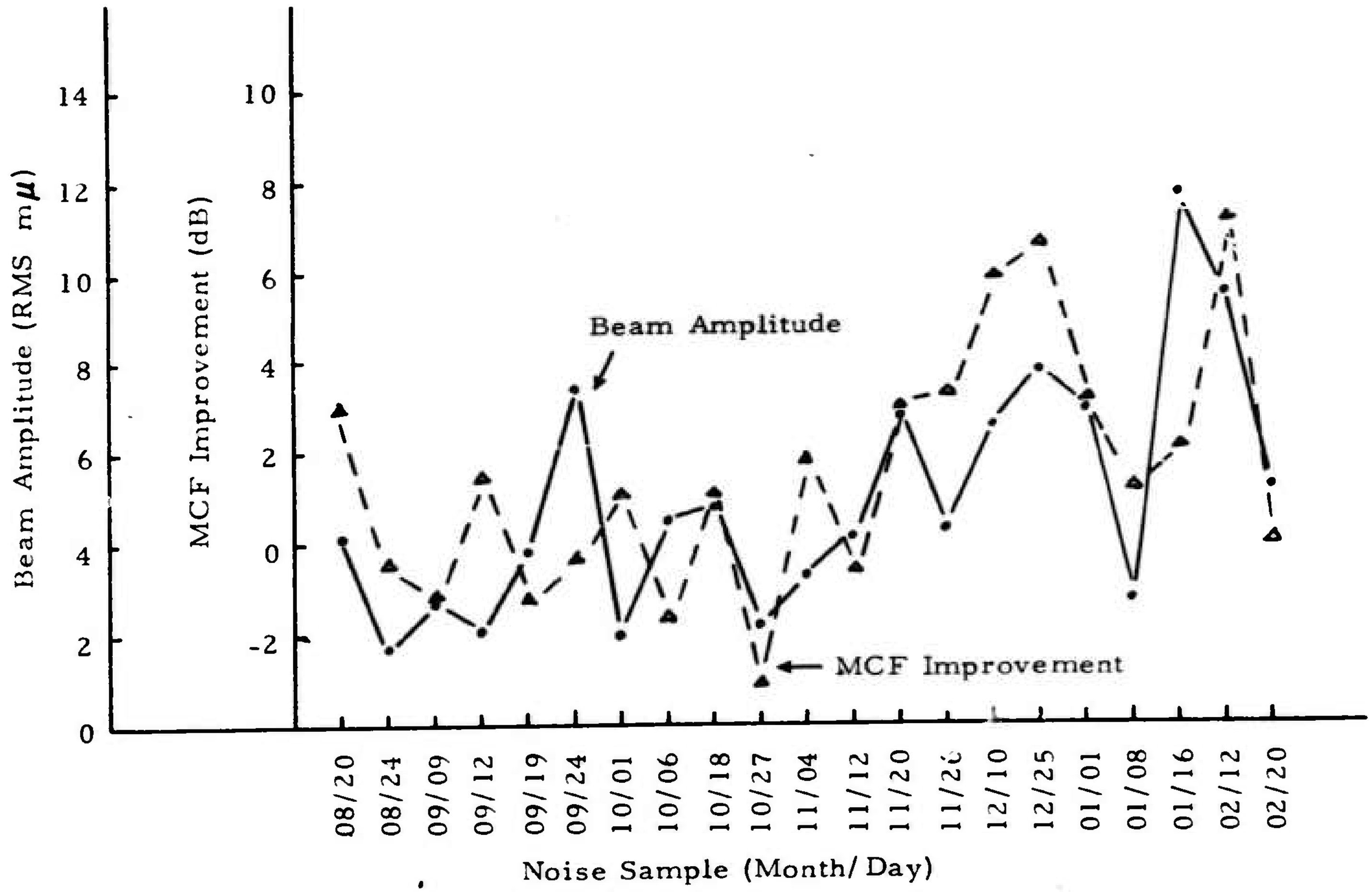


FIGURE IV-1

FULL ARRAY MCF IMPROVEMENT IN NOISE REJECTION AND BEAMSTEER OUTPUT LEVEL VERSUS NOISE SAMPLE (OFF-DESIGN NOISE 0.025 - 0.059 Hz or 17-40 sec)

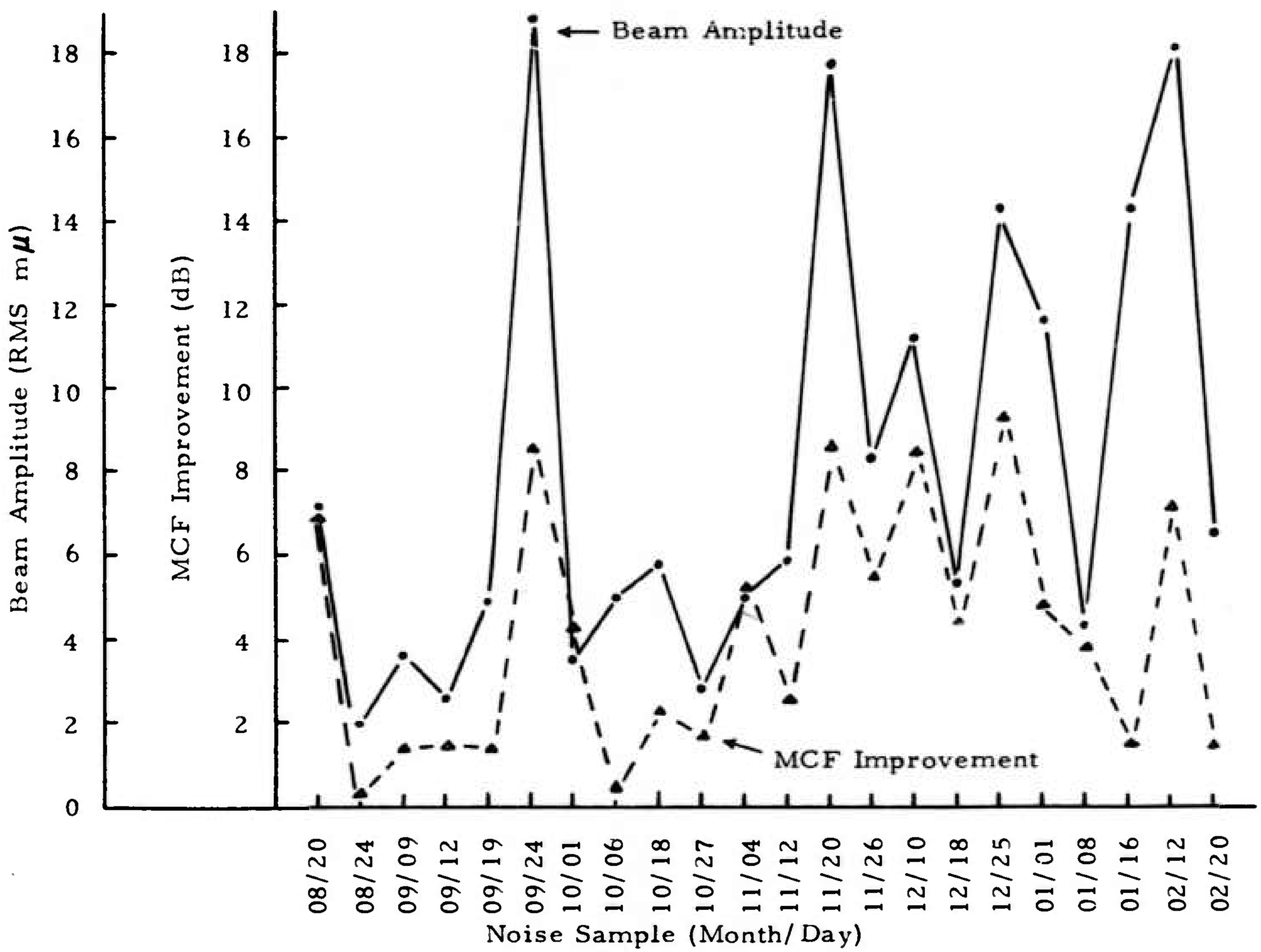


FIGURE IV-2

REDUCED ARRAY MCF IMPROVEMENT IN NOISE REJECTION AND BEAMSTEER OUTPUT LEVEL VERSUS NOISE SAMPLE (OFF-DESIGN NOISE 0.025 - 0.059 Hz or 17-40 sec)

D. SIGNAL DEGRADATION OF MCF AND BEAMSTEER PROCESSORS

The signal amplitude degradation of the beamsteer processor was measured using twelve 1972 winter ensemble events and sixteen 1972 summer ensemble events. Seven of the summer events were also MCF processed for comparison. Both the full array and the reduced array were used for these measurements.

Events were selected to have at least a moderate signal-to-noise ratio on both the reference site (usually site 1) and the output beam traces. Amplitude degradation of the unfiltered signal was measured by taking the ratio of the amplitude of a particular wave cycle from the reference site to the amplitude of the same cycle of the output beam. Three such ratios were averaged for each trace and the average ratio was then expressed in decibels.

Table IV-2 shows the signal loss of the beamsteer processor for the full and reduced arrays. Negative values indicate that the output beam amplitudes exceeded the reference site amplitude. Rayleigh wave signal loss ranged from -0.8 to 6.2 dB for the full array and -0.6 to 3.1 dB for reduced array with averages of 2.0 dB and 1.4 dB respectively. The beamforming loss of the Rayleigh and Love waves are not significantly different. The smaller loss of the reduced array is significant, however, and reflects the high signal similarity among the inner ring sites. Loss contributed by errors in the estimated phase velocity used for beamforming is also less for the reduced array.

The average signal degradation obtained for these events are approximately 1.0 to 1.4 dB larger than those obtained from the 1971 events. The reasons for this are not clear. The measurement technique of the earlier results was slightly different, using only one wave cycle instead of three. This has contributed a part of the difference. A second possibility is that one of the channels had inverted polarity causing partial cancellation of the signal for a few of the events. However, periodic checks of the data were made to check for that condition.

TABLE IV-2

SIGNAL AMPLITUDE DEGRADATION OF BEAMSTEER PROCESSOR FOR NORSAR FULL ARRAY AND ITS REDUCED ARRAY

Event Name	Signal Degradation (dB)					
	Full Array			Reduced Array		
	No. of Sites	Rayleigh Wave	Love Wave	No. of Sites	Rayleigh Wave	Love Wave
SIN*002*10	19	0.3	0.5	7	1.8	1.0
TAI*004*12	17	0.3	0.7	6	0.3	0.4
TAI*006*06	16	2.5	1.4	7	1.6	0.4
IRA*006*09	16	2.5	1.6	7	1.8	1.4
SIB*013*17	19	1.2	2.9	6	0.8	2.0
SIN*042*05	18	(-0.8)	1.9	8	(-0.6)	1.9
SIN*047*23	16	0.7	-	7	0.6	-
KUR*057*02	18	2.0	1.3	8	1.2	0.6
YUN*057*18	17	1.9	1.4	6	2.1	2.1
TIB*075*06	20	2.7	4.2	8	2.0	4.9
KUR*077*07	19	3.2	3.5	8	0.8	1.4
TAD*077*09	19	1.6	3.9	8	0.2	3.8
WRS*204*05	18	2.1	-1.7	7	2.1	-0.9
TIB*204*16	17	0.7	2.1	7	0.7	0.3
KUR*209*00	16	3.9	1.2	7	1.9	0.9
KUR*211*21	19	3.9	0.8	6	1.5	0.6
KAM*216*12	18	1.7	3.2	8	1.1	1.8
IRA*216*22	18	1.7	-	7	1.0	-
TUR*216*21	19	0.9	1.5	8	0.9	1.5
TUR*217*05	19	2.0	1.6	8	2.0	1.4
IRA*221*19	14	4.0	5.6	6	3.0	4.2
BAI*222*19	12	0.3	1.0	7	0.7	-0.2
ERS*222*20	17	6.2	3.2	6	2.4	-
MON*231*12	13	2.1	2.0	7	0.5	-
KUR*231*21	14	3.2	-	7	3.1	-
CHI*243*15	18	0.5	1.3	7	0.8	0.5
SIN*243*17	18	2.4	6.4	7	2.4	5.3
CHI*243*18	18	0.6	2.1	7	1.0	0.6
Average		2.0	2.2		1.4	1.6

Table IV-3 gives the vertical Rayleigh wave signal loss from the MCF processor. The beamsteer losses are included from Table IV-2 for comparison. Average MCF signal losses for the full and partial arrays were 3.2 dB and 2.3 dB respectively. This is close to the average beamsteer loss for these events of 2.9 dB and 1.8 dB respectively.

The event ERS*222*20 had a very high Rayleigh wave loss of 6.2 dB for the full array but a near-average loss of 2.4 dB for the partial array. This event was found to have significant off-azimuth (probably multipath) energy. The Love waves from this event showed no unusual behavior.

E. MCF PROCESSING OF SIGNALS USING ONE NOISE SAMPLE FOR MCF DESIGN

Earlier results (Texas Instruments, Special Report No. 7, 1973) have shown that a single noise sample might be useful for design of multichannel filters to be applied to events, days or weeks before or after the noise sample itself. This implies that either the noise field is generally stationary or that it changes slowly, perhaps gradually reducing the effectiveness of the MCF. This possibility would permit routine MCF processing of the data without the considerable expense in computer time needed to estimate cross-power spectral matrices. To further investigate the possibilities of this idea, 31 events occuring between the third and the eighteenth of August 1972 were processed using MCF's designed from the 7 August 1972 noise sample. These events are listed in Table IV-4. The MCF design noise sample had typical summertime characteristics of low level and isotropy.

Figure IV-3 shows the MCF/BS relative noise reduction in the 0.025-0.059Hz signal band computed in a 1500-second gate prior to the P-wave arrival of each event. Among the thirty-one events, sixteen favored the MCF

TABLE IV-3

SIGNAL AMPLITUDE DEGRADATION OF RAYLEIGH WAVE FROM MCF AND BEAMSTEER PROCESSOR FOR NORSAR FULL ARRAY AND ITS REDUCED ARRAY

Event Name	Signal Degradation (dB)					
	Full Array			Reduced Array		
	No. of Sites	MCF	BS	No. of Sites	MCF	BS
TUR*216*21	19	0.8	0.9	8	1.4	0.9
IRA*216*22	18	2.4	1.7	7	1.6	1.0
TUR*217*05	19	1.2	2.0	8	1.6	2.0
IRA*221*19	14	2.8	4.2	6	2.8	3.0
ERS*222*20	17	6.6	6.2	6	3.0	2.4
MON*231*12	13	4.0	2.1	7	1.7	0.5
KUR*231*21	14	4.7	3.2	7	4.1	3.1
Average		3.2	2.9		2.3	1.8

TABLE IV-4

MCF PROCESSED EVENT LIST

Event	SNR Computed	Event	SNR Computed
KAM*216*12NL	X	ERS*222*14NL	
TUR*216*21NL	X	BAI*222*19NL	X
IRA*216*22NL	X	ERS*222*20NL	X
RYU*216*22NL		HNK*223*01NL	X
KUR*217*04NL		KAM*226*18NL	
TUR*217*05NL	X	KUR*228*22NL	
IRA*217*09NL	X	AFG*229*10NL	
KUR*217*17NL	X	KOM*229*10NL	
KUR*217*18NL		KUR*229*12NL	X
KUR*218*00NL		KUR*229*19NL	X
IRA*219*07NL	X	KAM*229*21NL	
KUR*219*10NL	X	PAK*231*10NL	X
KOM*219*14NL		MON*231*12NL	X
KAM*221*17NA	X	KAM*231*18NL	X
IRA*221*19NL	X	KUR*231*21NL	X
KUR*222*10NL			

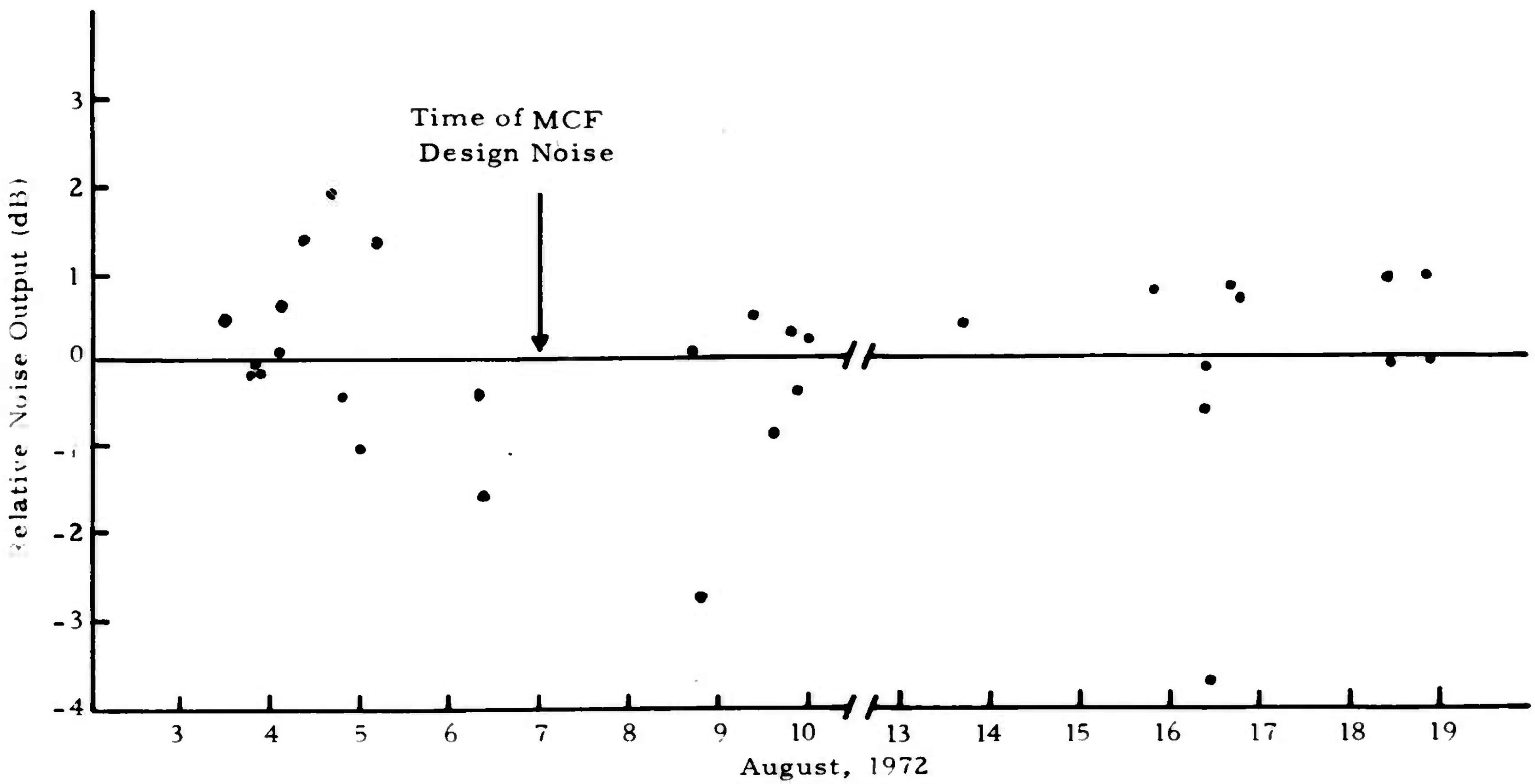


FIGURE IV-3

RATIO OF BEAMSTEER TO MCF NOISE OUTPUT
(0.025 - 0.059 Hz)

and fifteen the beamsteer. Although not shown, other passbands also were computed. In general, the results are in agreement with those shown in Table IV-1. That is, the MCF was superior in wider bands with higher frequencies, but not in narrow, lower frequency bands. Figure IV-3 shows that the MCF/ BS relative gains are rather randomly distributed positively and negatively and that they do not seem to be a function of the event-noise sample time separation indicating that the supposed necessity of using a noise sample close to the signal may not always be valid.

Nineteen of these events had good signal-to-noise ratio (SNR) and were suitable for comparison of MCF/BS SNR enhancement. Figure IV-4 shows the relative MCF/BS SNR's for the 0.025-0.059 Hz band. Because signal loss for the MCF and BS are about the same, the SNR's were mostly affected by noise reduction and consequently, the results were close to that of the noise analysis shown in Figure IV-3.

The results of this investigation show that although the summer noise is well-behaved, its almost isotropic character allows an MCF little advantage over a conventional beamsteer processor. On the other hand, the directional nature of winter noise which offers definite MCF improvements, is complicated by severe level changes and other transient phenomena which would effectively limit the use of fixed MCF's. Time-adaptive multichannel filters would seem to offer strong potential for eliminating the directional noise while coping with the transient level changes and should be investigated in any future analysis.

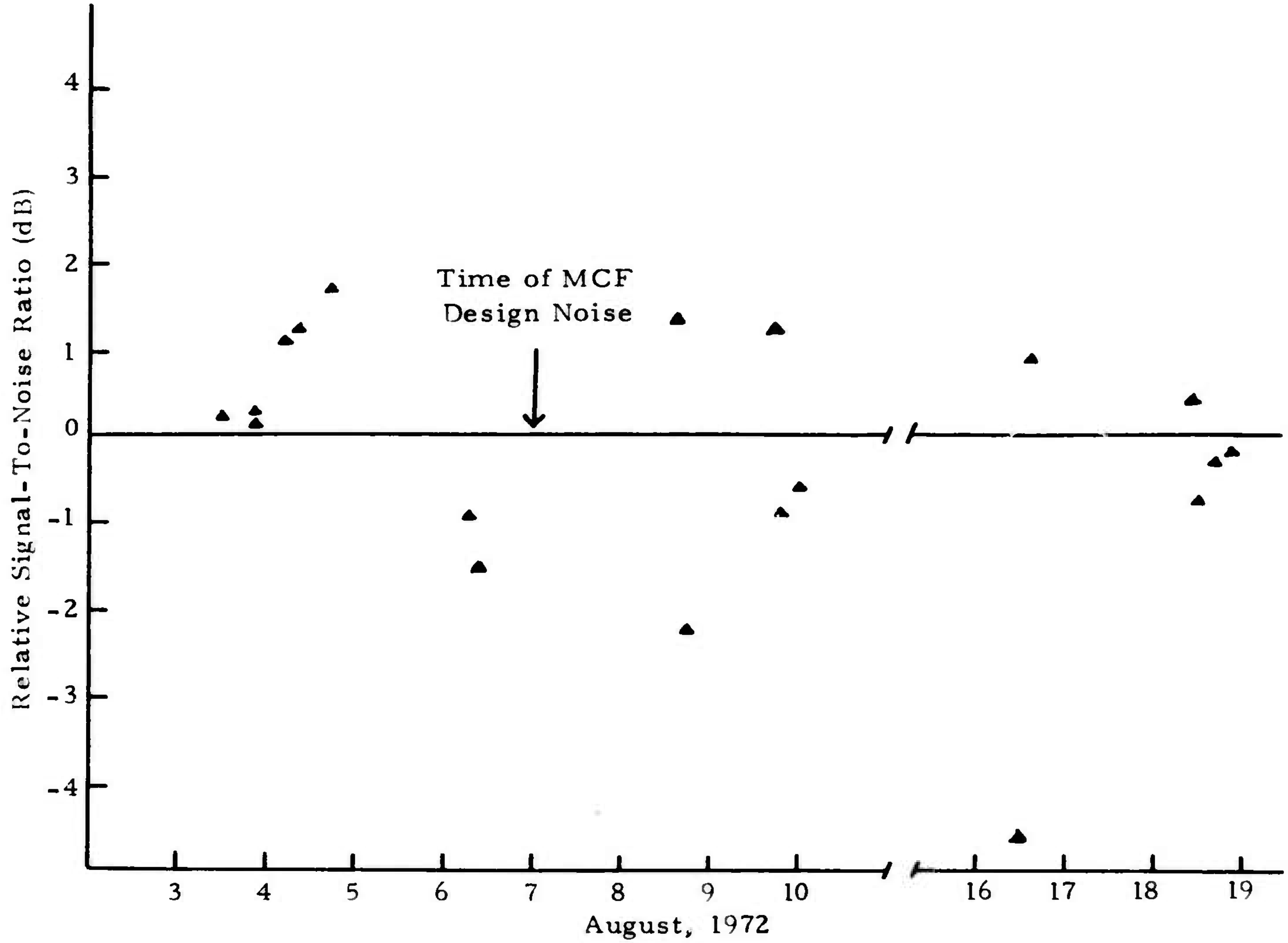


FIGURE IV-4

THE RELATIVE MCF/BS SIGNAL-TO-NOISE RATIOS
(0.025 - 0.059 Hz)

SECTION V

MATCHED FILTER PERFORMANCE

A. INTRODUCTION

The goals of the matched filter performance study were to determine the available signal-plus-noise-to-noise ratio (SNNR) improvements of the matched filters as compared to a bandpass filter and to regionalize the events by matched filter parameters.

The matched filters used in previous studies have been linear group velocity chirp filters (linear with frequency) and reference waveform filters (RWF). Because RWF's did not show a clear-cut superiority over chirp filters in SNNR gain (Special Report No. 5, 1972) and there was no *a priori* means of selecting "good" reference waveforms as filters (Special Report No. 5, 1973) this report is solely concerned with linear group velocity chirps. Appendix D contains a study of the limitations and errors involved using this linear frequency design.

B. PROCESSING

A suite of five chirp filters and one bandpass filter (0.020-0.059 Hz or 17-50 seconds in 1971; 0.025-0.059 Hz or 17-40 seconds in 1972 and 1973) were routinely applied to the three component beamsteered traces of each event. The lengths of the five chirps were determined, at first empirically and later from the maps of optimum chirp lengths described in Special Report No. 7.

The SNNR of a signal was measured as the ratio of zero-to-peak signal amplitude to the RMS noise amplitude. The signal was picked as the

maximum amplitude within a signal gate determined by a velocity range of 4.0 km/sec to 2.5 km/sec and the noise was measured over a 1200 second gate usually immediately preceding the P-wave arrival. The optimum chirp length was the length which produced the highest zero-to-peak amplitude.

C. REGIONALIZATION BY CHIRP FILTER LENGTH

An additional 96 LR vertical and 93 LQ transverse optimum chirp filter lengths were added to the data of Special Report No. 7 and were used to update the maps of optimum LR vertical and LQ transverse chirp lengths. Several events which were listed in Special Report No. 7 as having non-optimum chirp lengths were re-analyzed. Most of these events were from Taiwan, with the rest from central Asia and the Mediterranean area.

Figures V-1 and V-2 show the results of the entire ensemble contoured on the Eurasian Continent. During contouring it was assumed that the chirp length would increase monotonically with distance from NORSAR. The data also were smoothed to show regional variations rather than point to point variations. The contours have changed little from Special Report No. 7. The region of the Caspian Sea still shows the extraordinarily long chirp lengths which cannot be reconciled with the monotonicity rule.

The regionalization is suggested by changes in the direction and gradient of the contours. Figure V-3 shows the seismic regions derived from the chirp length maps. These regions are essentially unchanged from Special Report No. 7. As Appendix D shows, the optimum chirp length is not only a function of dispersion but also of the signal spectrum received at the array. The signal spectrum usually has been modified by the effects of radiation pattern, multipath interference, and attenuation. While these effects are important considerations in any regionalization scheme, they have been neglected here. Signal spectrum effects are most likely the cause of the unusual chirp behavior around the Caspian Sea.

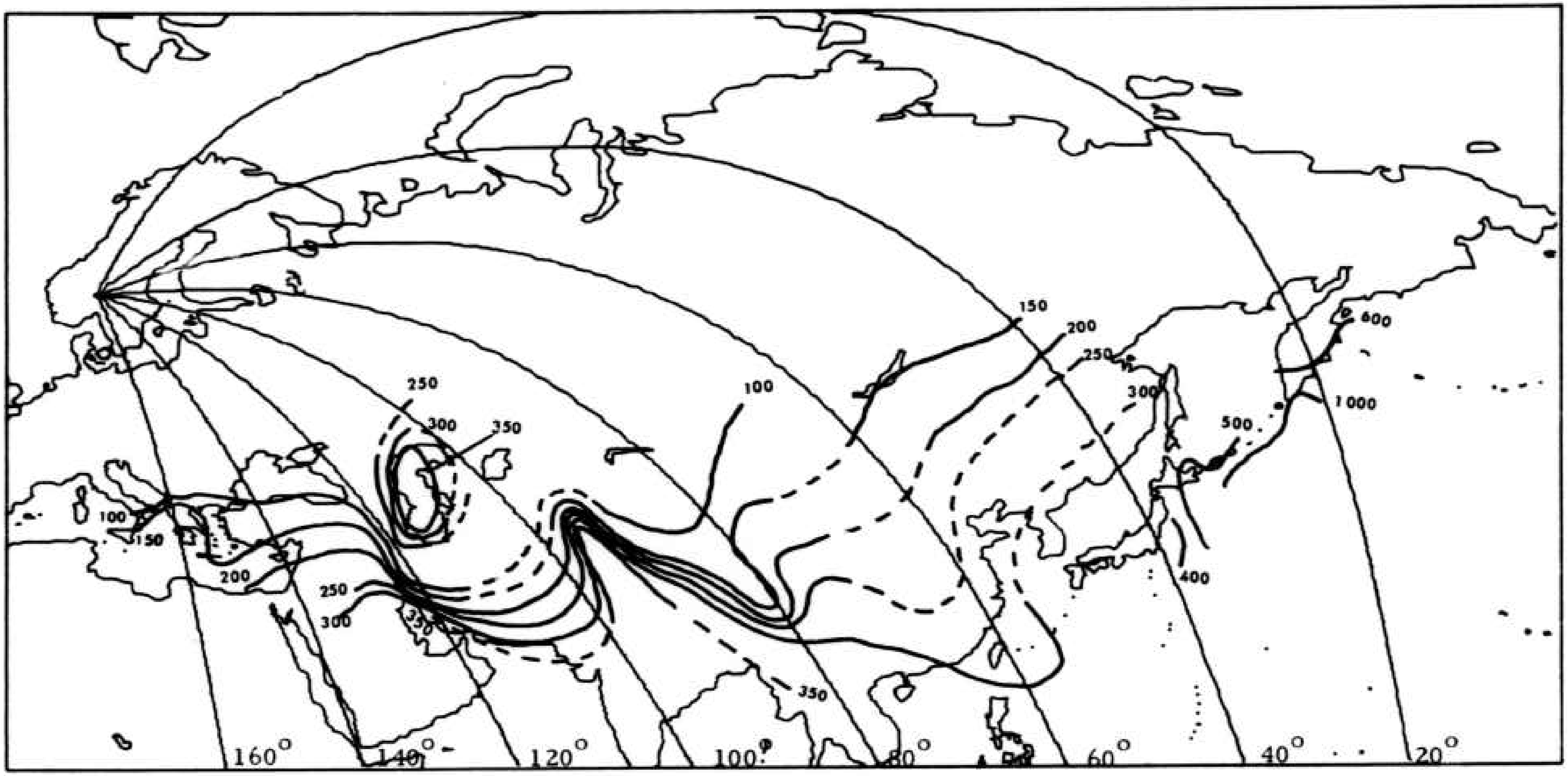


FIGURE V-1

OPTIMUM CHIRP FILTER LENGTHS (IN SECONDS) FOR LOVE WAVES AT NORSAR FOR THE PASSBAND 0.025-0.059 Hz

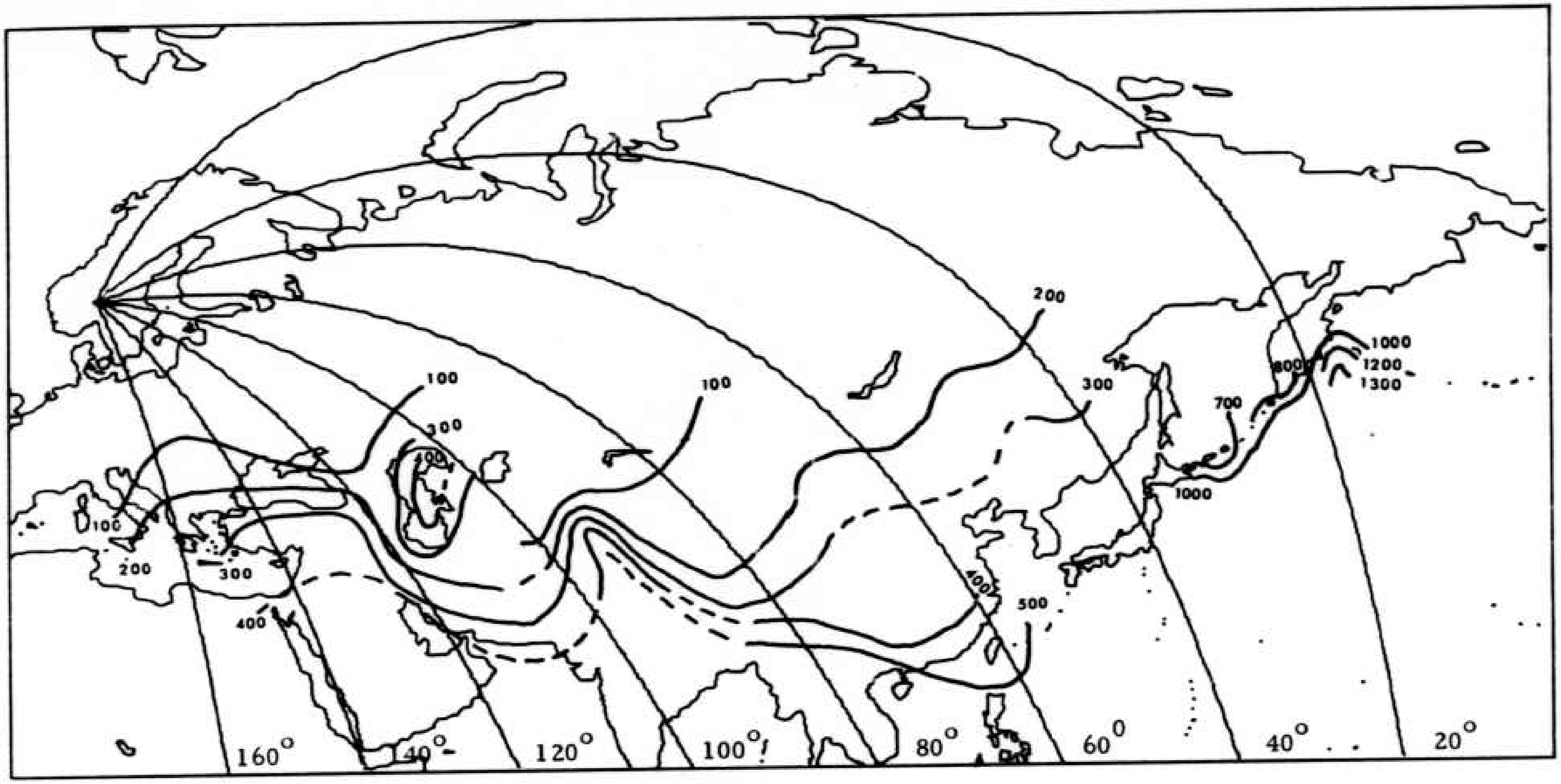


FIGURE V-2

OPTIMUM CHIRP FILTER LENGTHS (IN SECONDS) FOR RAYLEIGH WAVES AT NORSAR FOR THE PASSBAND 0.025-0.059 Hz

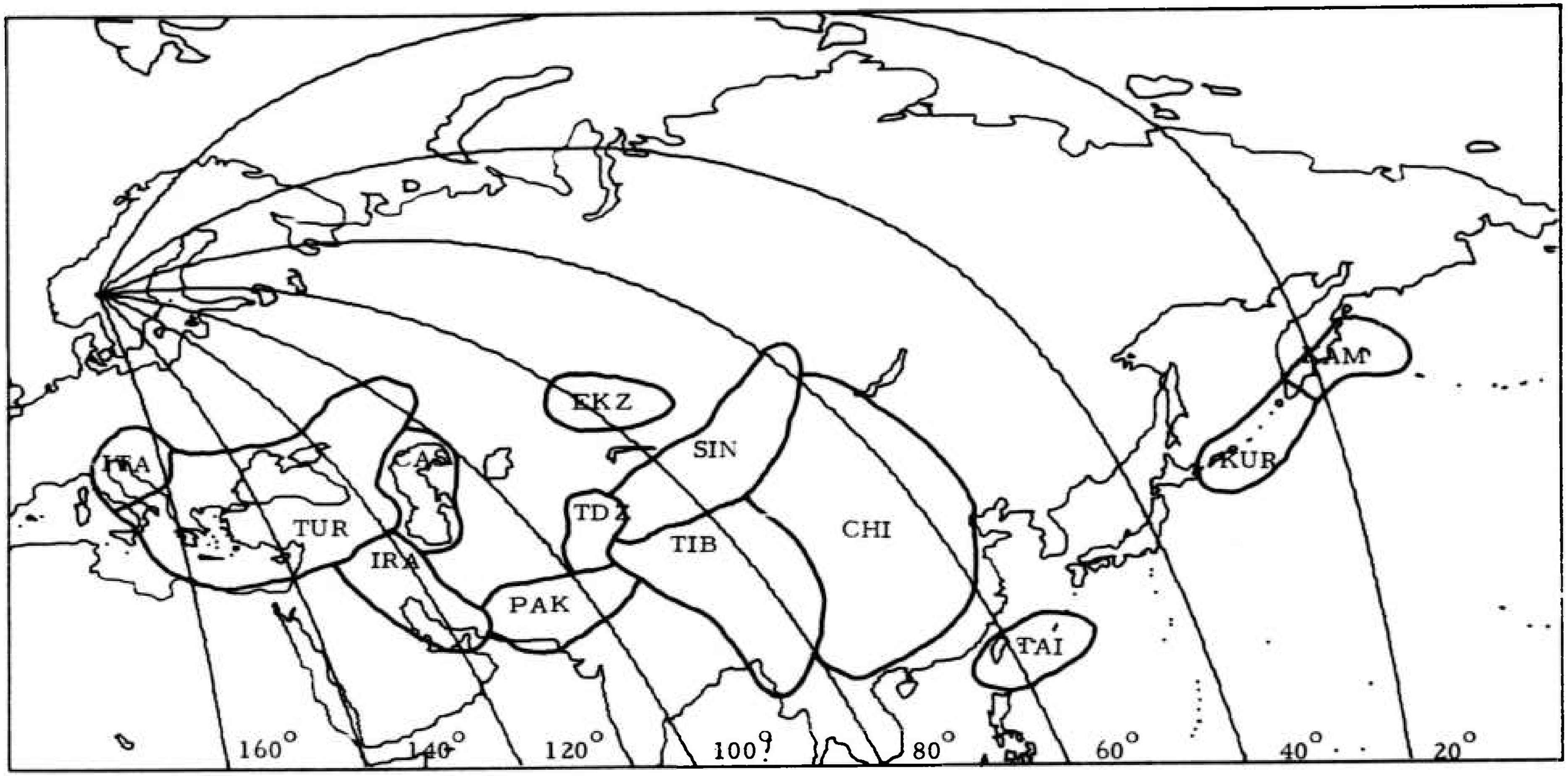


FIGURE V-3

SEISMIC REGIONS DERIVED FROM CHIRP FILTER ANALYSIS

D. CHIRP FILTER SNNR IMPROVEMENT

The average chirp filter SNNR improvement was computed for the events in each of the seismic regions shown in Figure V-3. The individual chirp gains for each event within each region are given in Table V-1. Included in Table V-1 are the best chirp lengths, SNNR of the bandpassed beam, the improvement of the chirp filter SNNR over the bandpassed beam SNNR, and the averages of chirp filter improvements by region. Non-detection on a particular component is indicated by a dash. Events with a SNNR less than 6.0 on the bandpassed data were not used in the computation of the average improvement and are indicated by an asterisk. Chirp lengths which are not considered to be optimum are also indicated by an asterisk and likewise are not included in the computations.

The majority of regions have an average from 1 to 2 dB SNNR improvement with matched filtering. The exceptions are the Eastern Kazakh test area which have poor chirp filter improvements (less than 1 dB) and the Western Pacific area from Taiwan to the Kuriles, which have improvements above 3 dB. The results of these data differ little from Special Report No. 7 except in the Taiwan region where re-analysis of several previous events has improved the average gain in that region.

Omitting those events with a bandpassed SNNR of less than 6, 87 percent of the Love wave chirps have positive SNNR improvement and 45 percent have 2 dB or greater improvement. For the Rayleigh wave 91 percent of the chirps have positive SNNR improvement and 50 percent have improvements greater than 2 dB. At ALPA, 60 percent of the Rayleigh wave chirp improvements exceeded 2 dB. A 2 dB increase in SNNR is equivalent to about an increase of 0.1 m_b units. For the 1972 winter events (Section VI), for example, this increase in apparent magnitude would raise events at the 50 percent detection level to the 62 percent level and events at the 90 percent detection level to the 93 percent level.

TABLE V-1

CHIRP MATCHED FILTER IMPROVEMENT IN SIGNAL+NOISE/NOISE RATIO
(PAGE 1 OF 16)

REGION 'ITA' - CENTRAL ITALY, AUSTRIA, NORTHERN YUGOSLAVIA

EVENT	CHIRP LENGTH			BANDPASSED SNNR			SNNR IMP (DB)		
	LQT	LRV	LRR	LQT	LRV	LRR	LQT	LRV	LRR
AUS*005*04	80	100	100	16.3	11.7	8.9	0.1	3.7	2.6
AUS*169*09	70	120	120	12.3	20.4	14.6	1.3	3.2	2.9
ITA*035*02	65	85	85	224.4	62.7	53.3	1.9	1.1	-.2
ITA*035*09	75	65	65	131.3	31.4	24.5	0.3	0.6	0.2
ITA*035*17	75	65	105	114.6	29.5	25.7	0.3	0.8	-.4
ITA*035*19	75	65	65	25.9	8.5	4.4*	1.4	0.3	0.0
ITA*036*05	65	95	95	22.8	12.5	10.7	0.8	-.6	-.3
ITA*036*07	55	105	105	38.4	23.3	19.8	0.9	0.2	-.2
ITA*036*15	75	95	85	98.3	34.9	34.6	2.0	0.2	-1.2
ITA*037*01	65	65	65	88.0	22.1	24.1	1.7	0.3	-.1
ITA*037*21	90	-	-	12.7	-	-	1.9	-	-
ITA*039*12	75	105	105	23.9	10.4	10.4	1.3	-.6	0.3
ITA*166*18	65	180	180	847.7	469.4	381.9	1.2	4.0	2.7
ITA*166*21	65	110	110	99.1	28.7	16.0	1.5	0.1	-.2
YUG*177*04	80	160	160	6.3	15.8	7.3	0.9	3.3	3.0
YUG*180*01	80	175	150	42.7	11.9	9.8	1.5	3.0	1.8
ITA*331*16	220	200	-	271.0	69.6	-	-3.2	1.4	-
ITA*335*11	220	200	-	10.3	8.4	-	-1.7	2.5	-
YUG*225*23	160	220	220	246.0	92.3	66.4	2.6	2.3	2.1
YUG*243*00	100	100	180	14.2	3.2*	3.1*	1.0	1.5	1.3
						MEAN SNNR IMPROVEMENT =	0.89	1.43	0.99
						STANDARD DEVIATION =	1.30	1.53	1.67
						NUMBER OF EVENTS =	20	18	15

TABLE V-1

CHIRP MATCHED FILTER IMPROVEMENT IN SIGNAL+NOISE/NOISE RATIO
(PAGE 2 OF 16)

REGION 'TUR' - GREECE,TURKEY,BLACK SEA,E EUROPE,E MEDITERRANEAN

EVENT	CHIRP LENGTH			BANDPASSED SNNR			SNNR IMP (DB)		
	LQT	LRV	LRR	LQT	LRV	LRR	LQT	LRV	LRR
BLS/263/06	130	217	217	0.0	0.0	0.0	1.3	3.8	3.3
BLS/263/10	383	235	235	0.0	0.0	0.0	3.2	3.0	1.9
CAU/283/09	87	87	87	0.0	0.0	0.0	1.0	0.9	0.3
TRS/251/22	108	217	217	0.0	0.0	0.0	2.6	2.6	2.6
TUR/126/04	122	348	348	0.0	0.0	0.0	3.2	5.3	4.2
TUR/143/01	108	305	305	0.0	0.0	0.0	2.5	6.5	6.4
TUR/161/09	139	283	283	0.0	0.0	0.0	4.8	5.6	4.9
BUL*068*22	300	450*	450*	12.8	32.1	14.0	4.4	3.6	2.9
CAU*079*03	100	-	100	16.6	-	5.2*	-1.5	-	1.3
CAU*208*18	60	160	200	21.1	26.1	13.2	0.4	1.8	2.0
CRE*017*05	100	400	400	6.4	5.1*	4.3*	1.3	2.7	2.9
CRE*026*12	-	250	-	-	2.3*	-	-	-2.1	-
CRE*161*07	160	250	250	179.0	161.4	110.7	0.5	3.8	2.7
DOD*020*02	100	300	300	26.8	64.0	55.5	1.3	3.1	3.9
GRE*002*09	150	280	280	4.7*	4.1*	4.8*	2.0	2.6	0.5
GRE*012*13	250	300	-	67.5	126.2	-	2.7	4.1	-
GRE*033*21	220	280	280	42.8	26.0	10.4	1.4	2.0	2.2
GRE*044*13	150	240	240	43.8	15.4	11.3	1.6	-.8	0.7
GRE*047*00	150	280	240	51.8	11.0	12.5	2.1	-.8	0.2
GRE*157*10	100	280	320	138.1	69.2	70.5	-.2	2.3	2.3
GRE*167*00	180	320	280	614.1	562.9	403.1	3.1	5.8	5.3
GRE*190*05	75	240	240	11.7	12.8	9.5	1.0	4.2	5.5
GRE*200*13	140	160	-	21.9	15.1	-	3.3	1.7	-
MED*191*13	100	-	-	14.1	-	-	2.2	-	-
MED*199*03	220*	280	280	24.4	14.8	18.4	1.1	3.4	1.2
MED*205*18	160	280	280	9.1	15.2	8.7	1.7	3.1	3.8
SWR*277*08	50	40	60	9.8	25.6	13.2	0.4	0.3	0.6
TRS*160*12	100	280	320	13.2	5.9*	5.1*	0.4	2.1	1.6
TUR*022*17	125	250	250	4.4*	4.6*	4.0*	1.9	3.2	2.8
TUR*156*16	125	250	300	12.0	8.4	7.4	3.0	2.5	2.2
TUR*170*22	100	320	320	15.2	8.7	9.2	2.8	2.9	-1.7
TUR*173*05	75	100	100	39.4	65.6	38.5	0.9	-.1	0.8
TUR*175*04	120	240	280	31.0	23.8	14.0	3.4	5.2	4.0
TUR*186*06	100	240	-	8.3	13.7	-	2.1	0.5	-
TUR*198*02	120	320*	320*	575.4	335.1	270.0	2.3	3.7	3.6

TABLE V-1

CHIRP MATCHED FILTER IMPROVEMENT IN SIGNAL+NOISE/NOISE RATIO
(PAGE 3 OF 16)

REGION 'TUR' - GREECE,TURKEY,BLACK SEA,E EUROPE,E MEDITERRANEAN

EVENT	CHIRP LENGTH			BANDPASSED SNNR			SNNR IMP (DB)		
	LOT	LRV	LRR	LOT	LRV	LRR	LOT	LRV	LRR
TUR*206*10	100	320	320	34.2	24.4	19.2	1.9	3.6	2.2
GRE*235*02	250	200	200	7.3	8.5	5.9*	0.3	3.2	2.6
GRE*242*22	260	230	230	11.4	12.4	9.2	1.5	3.7	3.7
GRE*310*19	200	400	400	34.2	53.6	29.9	1.8	6.5	6.2
GRE*311*09	150	250	-	5.4*	3.2*	-	-.9	0.4	-
GRE*321*03	-	350	-	-	3.8*	-	-	2.0	-
GRS*244*14	160	-	-	342.8	-	-	2.0	-	-
CYP*215*15	150	200	200	90.7	14.6	24.9	1.9	1.5	0.9
DOD*219*10	180	230	-	18.5	27.3	-	2.8	-.6	-
GRE*231*08	100	320	320	36.0	25.6	20.6	1.4	4.0	5.0
GRE*232*06	140	290	290	8.8	12.2	4.7*	-.2	5.0	2.8
GRE*325*03	260	200	200	24.0	18.0	20.1	0.9	4.1	4.3
GRE*329*01	180	260	260	52.9	35.9	20.9	2.1	3.1	3.1
GRE*329*03	180	260	260	145.7	294.3	144.0	4.0	2.3	2.1
GRE*330*15	220	260	230	4.8*	4.1*	5.8*	0.7	4.1	1.7
MED*219*03	150	250	250	22.4	15.3	15.0	-1.1	4.1	2.5
MED*242*21	200	250	250	31.7	37.8	25.3	1.0	3.8	4.9
MED*320*12	150	[illegible]	350	10.1	7.6	7.3	3.6	1.9	0.6
MED*333*13	350	[illegible]	400	10.6	26.6	20.8	5.2	0.7	0.3
MED*334*01	-	200	-	-	3.6*	-	-	-.2	-
TUR*216*02	100	200	200	192.3	67.7	49.4	1.2	0.7	1.9
TUR*216*21	130	200	200	309.1	151.3	102.2	1.5	1.0	-.1
TUR*217*05	160	240	-	126.6	43.1	-	1.1	1.9	-
TUR*220*05	130	320	240	14.7	14.4	3.0*	1.5	0.4	3.1
TUR*236*21	130	240	280	10.8	5.2*	5.3*	0.8	4.9	4.4
WRS*204*05	80	120	-	23.4	58.4	-	1.4	0.5	-

MEAN SNNR IMPROVEMENT = 1.80 2.69 2.62
STANDARD DEVIATION = 1.36 1.91 1.94
NUMBER OF EVENTS = 53 46 37

TABLE V-1

CHIRP MATCHED FILTER IMPROVEMENT IN SIGNAL+NOISE/NOISE RATIO
(PAGE 4 OF 16)

REGION 'CAS' - CASPIAN SEA, EASTERN CAUCASUS

EVENT	CHIRP LENGTH			BANDPASSED SNNR			SNNR IMP (DB)		
	LOT	LRV	LRP	LOT	LRV	LRP	LOT	LRV	LRP
CAS/135/04	287	69	69	0.0	0.0	0.0	3.4	1.2	1.0
CAU/262/06	-	392	-	-	0.0*	-	-	0.0	-
CAU/288/17	305	453	453	0.0	0.0	0.0	2.5	2.3	3.4
WK7/356/06	261	174	174	0.0	0.0	0.0	1.9	1.4	1.2
CAU*166*00	350	300	300	22.6	74.4	44.0	0.2	1.3	1.0
IRA*018*21	120	600	600	43.1	16.7	13.2	-.2	3.9	1.5
						MEAN SNNR IMPROVEMENT =	1.57	2.03	1.63
						STANDARD DEVIATION =	1.52	1.13	1.01
						NUMBER OF EVENTS =	5	5	5

TABLE V-1

CHIRP MATCHED FILTER IMPROVEMENT IN SIGNAL+NOISE/NOISE RATIO
(PAGE 5 OF 16)

REGION 'IRA' - SOUTHERN IRAN

EVENT	CHIRP LENGTH LOT	CHIRP LENGTH LRV	CHIRP LENGTH LPR	BANDPASSED SNNR LOT	BANDPASSED SNNR LRV	BANDPASSED SNNR LPR	SNNR IMP (DB) LOT	SNNR IMP (DB) LRV	SNNR IMP (DB) LPR
IRA*006*09	300*	420	-	47.4	31.1	-	-2.4	0.8	-
IRA*014*22	250*	560	560	93.6	33.4	19.8	-2.1	-.8	2.1
IRA*041*09	200	440	440	21.8	7.7	6.6	-.8	1.7	2.6
IRA*041*16	450	400	400	11.8	23.5	8.5	0.9	0.0	1.0
IRA*068*21	350	-	400	19.4	-	22.8	0.2	-	2.7
IRA*155*08	160*	360	-	11.3	3.9*	-	0.4	1.7	-
IRA*156*03	-	540	540	-	3.3*	4.7*	-	5.5	0.6
IRA*157*11	160*	300	360	45.4	8.8	8.8	-2.3	1.7	-1.1
IRA*162*19	160*	480	480	63.6	20.7	15.9	-1.6	2.3	3.5
IRA*164*13	100	350	350	367.0	68.4	76.3	0.6	2.3	1.5
IRA*165*00	160	540	480	444.9	148.0	120.0	-.4	3.4	3.5
IRA*168*23	160*	300	300	22.2	24.4	8.9	-2.4	0.7	1.2
IRA*175*08	160*	300	300	100.4	25.3	21.3	-.8	3.8	2.9
IRA*184*12	200*	-	-	1772.2	-	-	-1.6	-	-
IRA*184*14	90	350	300	2.9*	2.4*	2.6*	1.7	2.2	0.2
IRA*185*02	-	300	300	-	32.5	21.5	-	3.2	3.4
IRA*185*12	-	350	-	-	7.7	-	-	0.5	-
IRA*185*21	100	350	300	242.6	97.8	93.3	1.3	4.2	3.0
IRA*187*16	100	250	250	15.6	21.8	21.4	3.8	2.4	1.3
IRA*187*21	130	-	-	3.2*	-	-	1.4	-	-
IRA*188*05	-	350	350	-	6.1	5.7*	-	1.6	0.7
IRA*193*22	-	200	200	-	54.2	57.0	-	3.3	2.8
IRA*196*13	100	400	-	21.3	7.3	-	0.9	0.6	-
IRA*196*17	100	-	-	6.1	-	-	1.1	-	-
IRO*060*08	250	400*	400*	11.7	3.5*	4.4*	1.1	1.7	-2.4
IRA*216*22	190	200	-	4.7*	11.5	-	2.0	-.9	-
IRA*217*09	70	200	200	6.5	17.2	11.5	0.4	0.1	0.2
IRA*219*07	70	320	380	56.6	110.2	62.0	1.2	0.6	2.0
IRA*221*19	70	260	260	121.4	45.9	22.4	2.4	-.1	4.7
IRA*229*05	160	200	200	12.9	12.4	9.6	3.1	0.4	0.4
IRA*321*10	100	380	440	14.4	8.3	9.3	2.5	1.5	2.0
IRA*325*03	160	440	200	10.4	4.6*	5.8*	2.7	3.1	2.9
IRA*330*22	130	380	380	69.9	19.4	24.4	3.1	2.3	1.1
						MEAN SNNR IMPROVEMENT =	1.42	1.49	2.08
						STANDARD DEVIATION =	1.31	1.43	1.42
						NUMBER OF EVENTS =	17	24	20

TABLE V-1

CHIRP MATCHED FILTER IMPROVEMENT IN SIGNAL+NOISE/NOISE RATIO
(PAGE 6 OF 16)

REGION 'PAK' - PAKISTAN, EASTERN IRAN

EVENT	CHIRP LENGTH			BANDPASSED SNNR			SNNR IMP (DB)		
	LOT	LRV	LRR	LOT	LRV	LRR	LOT	LRV	LRR
IRA*029*09	200	360	360	4.2*	6.1	3.9*	-1.0	-1.2	0.9
IRA*193*15	220	-	-	4.2*	-	-	2.9	-	-
PAK*157*11	240	160	320	26.1	14.8	14.0	3.2	1.1	1.1
PAK*162*11	-	300	250	-	46.6	32.6	-	2.3	1.4
PAK*179*10	280	240	160	48.5	132.1	83.5	0.7	2.1	1.7
PAK*195*18	-	240	-	-	6.5	-	-	2.8	-
PAK*231*10	300	200	200	14.5	27.8	22.3	0.7	0.3	0.4

	LOT	LRV	LRR
MEAN SNNR IMPROVEMENT =	1.54	1.23	1.16
STANDARD DEVIATION =	1.45	1.51	0.55
NUMBER OF EVENTS =	3	6	4

TABLE V-1

CHIRP MATCHED FILTER IMPROVEMENT IN SIGNAL+NOISE/NOISE RATIO
(PAGE 7 OF 16)

REGION 'TDZ' - TADZHIK, KIRGIZ, HINDU KUSH, N AFGANISTAN

EVENT	CHIRP LENGTH			BANDPASSED SNNR			SNNR IMP (DB)		
	LQT	LRV	LRR	LQT	LRV	LRR	LQT	LRV	LRR
KRG/301/13	122	383	383	0.0	0.0	0.0	1.5	2.9	1.8
TDZ/147/00	348	392	-	0.0	0.0	-	2.1	3.6	-
TDZ/274/16	348	479	479	0.0	0.0	0.0	-3.2	3.7	3.8
AFG*059*18	250	-	400	6.6	-	13.5	3.8	-	4.2
AFG*181*03	100	400	400	54.1	65.6	50.2	0.8	-1.0	0.9
HNK*053*08	250	350	250	7.8	4.5*	3.7*	2.1	0.9	2.0
HNK*177*07	380	-	-	48.7	-	-	-1.4	-	-
KRG*006*05	80	100	130	4.1*	9.7	6.7	-1.5	0.3	2.2
TAD*077*09	400	350	350	69.3	136.3	121.0	1.3	1.0	1.7
TDZ*005*12	450	450	450	6.7	6.6	6.6	2.3	0.9	0.5
HNK*178*20	-	700	700	-	4.6*	5.0*	-	3.2	2.6
HNK*179*15	-	200	200	-	107.7	76.2	-	2.1	2.5
AFG*215*12	110	350	-	2.8*	2.1*	-	1.2	-.4	-
AFG*226*09	310	400	400	5.4*	9.7	6.5	0.4	3.1	2.8
AFG*229*10	160	-	-	4.1*	-	-	2.6	-	-
AFG*308*23	190	440	440	266.8	262.9	210.7	3.3	5.8	5.2
AFG*320*14	210	-	-	6.6	-	-	-1.8	-	-
HNK*223*01	160	400	400	14.6	4.3*	2.1*	0.7	-.5	2.9
HNK*240*16	110	300	300	2.0*	3.5*	2.0*	-.6	1.8	2.7
TDZ*311*12	100	120	120	19.2	11.3	11.1	3.0	1.2	1.9
						MEAN SNNR IMPROVEMENT =	1.12	2.14	2.50
						STANDARD DEVIATION =	2.09	1.91	1.41
						NUMBER OF EVENTS =	13	11	11

TABLE V-1

CHIRP MATCHED FILTER IMPROVEMENT IN SIGNAL+NOISE/NOISE RATIO
(PAGE 8 OF 16)

REGION 'TIB' - S SINKIANG, TIBET, N BURMA, HIMALAYAN MOUNTAINS

EVENT	CHIRP LENGTH			BANDPASSED SNNR			SNNR IMP (DB)		
	LOT	LRV	LRR	LOT	LRV	LRR	LOT	LRV	LRR
SIN/219/15	174	305	305	0.0	0.0	0.0	3.1	3.0	0.3
SIN/241/15	-	174	-	-	0.0*	-	-	0.7	-
TIB/123/00	196	305	305	0.0	0.0	0.0	4.5	1.2	3.5
TIB/155/20	305	479	479	0.0	0.0	0.0	3.2	1.0	1.6
TIB/302/17	217	87	87	0.0	0.0	0.0	2.3	1.0	1.2
BUR*160*16	350	600	700	19.7	26.5	13.7	3.2	-1.4	-.4
CHI*154*16	250	420	420	42.8	16.5	13.8	2.4	3.8	3.1
IND*154*20	250	640	-	10.8	7.5	-	1.9	-.7	-
TIB*075*06	300	300	300	40.7	37.1	24.0	0.7	2.0	2.8
TIB*160*23	120	100	175	16.4	5.8*	5.2*	1.9	1.0	2.3
TIB*170*04	240	360	360	35.2	36.2	14.3	-.9	3.2	1.1
TIB*195*05	200	-	-	6.7	-	-	3.2	-	-
TIB*198*02	250	-	-	66.4	-	-	3.4	-	-
TIB*198*03	200	-	-	10.6	-	-	2.0	-	-
TIB*204*16	150	200	200	5416.3	936.4	511.8	2.8	1.3	-1.0
TIB*204*21	150	-	-	27.9	-	-	3.7	-	-
TIB*205*23	150	-	-	8.6	-	-	3.5	-	-
TIB*206*14	150*	200*	200*	20.9	20.7	15.3	-.7	1.2	0.8
TIB*242*23	150	350	350	13.5	10.8	11.3	0.2	1.0	-1.2
SIK*234*14	400	400	400	18.4	36.9	18.6	0.5	-1.5	-.4
SIK*234*18	400	200	-	4.8*	4.2*	-	-.1	2.0	-
SIK*311*10	200	200	200	46.1	30.6	29.6	0.0	3.7	4.2

	LOT	LRV	LRR
MEAN SNNR IMPROVEMENT =	2.19	1.35	1.24
STANDARD DEVIATION =	1.45	1.79	1.84
NUMBER OF EVENTS =	19	13	12

TABLE V-1

CHIRP MATCHED FILTER IMPROVEMENT IN SIGNAL+NOISE/NOISE RATIO
(PAGE 9 OF 16)

REGION 'CHI' - CENTRAL CHINA

EVENT	CHIRP LENGTH			BANDPASSED SNNR			SNNR IMP (DB)		
	LOT	LRV	LRR	LOT	LRV	LRR	LOT	LRV	LRR
CHI/229/09	152	479	479	0.0	0.0	0.0	2.3	4.0	4.3
CHI/229/17	152	196	196	0.0	0.0	0.0	1.6	1.9	1.4
CHI/258/07	174	471	471	0.0*	0.0*	0.0*	2.5	3.2	3.1
CHI*034*07	180	550	550	37.7	12.3	9.7	2.3	1.3	2.3
CHI*189*23	380	-	-	15.9	-	-	1.5	-	-
CHI*203*16	310	400	400	38.3	69.6	29.9	5.8	3.6	4.6
MON*153*11	200	-	-	9.9	-	-	1.7	-	-
MON*244*17	150	-	-	6.1	-	-	2.6	-	-
YUN*057*18	200	300	600	45.7	33.2	20.3	0.5	-.3	-1.4
CHI*226*02	160	200	-	23.8	9.3	-	1.5	-.8	-
CHI*243*15	160	200	200	124.4	114.3	128.3	4.1	0.4	0.0

MEAN SNNR IMPROVEMENT = 2.39 1.52 1.88
STANDARD DEVIATION = 1.52 1.97 2.36
NUMBER OF EVENTS = 10 7 6

TABLE V-1

CHIRP MATCHED FILTER IMPROVEMENT IN SIGNAL+NOISE/NOISE RATIO
(PAGE 10 OF 16)

REGION 'SIN' - SOUTHWESTERN, WESTERN, NORTHWESTERN SINKIANG

EVENT	CHIRP LENGTH			BANDPASSED SNNR			SNNR IMP (DB)		
	LOT	LRV	LRR	LOT	LRV	LRR	LOT	LRV	LRR
SIN/166/22	87	174	174	0.0	0.0	0.0	1.6	1.2	0.0
SIN/166/23	95	217	217	0.0	0.0	0.0	1.4	-.6	-.2
SIN/170/17	108	217	217	0.0	0.0	0.0	0.7	1.3	1.9
SIN/221/01	104	78	78	0.0	0.0	0.0	1.9	0.6	0.3
CRS/236/16	113	239	-	0.0	0.0	-	2.6	2.5	-
SIN/273/12	104	174	174	0.0	0.0	0.0	1.7	1.5	0.4
BAI*058*22	100	300	300	7.7	12.2	8.4	1.2	2.7	2.5
FKZ*078*07	-	50	50	-	4.7*	3.3*	-	0.4	1.3
KRG*028*20	80	320*	320*	9.7	4.5*	3.7*	0.8	-1.8	-1.3
SIN*002*10	80	100	100	70.4	75.9	62.4	2.5	1.1	1.0
SIN*042*05	100*	100	100	53.3	70.6	52.6	0.9	1.1	0.4
SIN*047*23	80	150	150	17.1	31.8	22.4	0.8	0.5	0.8
SIN*064*04	100	200	200	19.3	44.6	19.1	-.2	0.7	1.0
SIN*154*06	80	175	-	29.0	5.8*	-	1.5	1.2	-
SIN*187*01	60	175*	175*	256.0	78.2	53.0	1.1	1.5	2.3
SIN*187*04	140	175	175	8.0	12.7	8.4	4.2	3.2	2.5
SIN*192*19	160	175	175	6.9	35.6	26.4	3.2	1.6	1.1
SIN*200*03	100	-	-	7.6	-	-	0.7	-	-
SIN*235*16	60	75	75	12.6	11.1	5.3*	0.4	1.7	2.4
SIN*243*17	120	75	75	1.9*	2.6*	2.8*	2.9	1.2	1.1
SIN*307*12	60	75	175	3.8*	2.6*	4.1*	1.9	0.3	-.6
SIN*316*14	60	75	150	4.5*	4.6*	3.4*	-.5	-.2	2.3
SIN*325*05	60	150	-	24.0	3.5*	-	1.1	1.4	-

	LOT	LRV	LRR
MEAN SNNR IMPROVEMENT =	1.51	1.37	0.97
STANDARD DEVIATION =	1.06	0.98	0.89
NUMBER OF EVENTS =	18	14	12

TABLE V-1

CHIRP MATCHED FILTER IMPROVEMENT IN SIGNAL+NOISE/NOISE RATIO
(PAGE 11 OF 16)

REGION 'EKZ' - EASTERN KAZAKH TEST AREA, CENTRAL KAZAKH

EVENT	CHIRP LENGTH			BANDPASSED SNNR			SNNR IMP (DB)		
	LOT	LRV	LPR	LOT	LRV	LRR	LOT	LRV	LPR
EKZ/145/04	-	113	-	-	0.0*	-	-	4.0	-
EKZ/157/04	91	200	200	0.0	0.0	0.0	1.3	1.8	0.2
EKZ/170/04	52	139	139	0.0	0.0	0.0	0.5	0.3	1.8
EKZ/282/06	-	139	-	-	0.0*	-	-	2.7	-
EKZ/294/06	39	122	122	0.0	0.0	0.0	0.9	0.8	-1.6
EKZ/333/06	52	69	69	0.0	0.0	0.0	1.4	0.5	1.1
EKZ/364/06	65	87	87	0.0	0.0	0.0	1.3	1.1	1.2
EKZ*070*04	50	100	100	10.0	9.9	6.6	1.0	1.4	1.2
EKZ*088*04	130	50	50	2.8*	4.0*	3.2*	4.2	0.1	0.3
EKZ*229*03	-	60	80	-	6.3	5.4*	-	0.2	0.1
EKZ*307*01	40	80	100	21.9	27.8	20.5	-.1	1.8	1.6
EKZ*345*04	50	50	75	77.3	34.0	29.1	-.3	0.9	1.1
WKZ*233*02	60	90	75	11.2	27.8	22.5	0.1	0.9	1.1
WRS*204*05	-	-	120	-	-	44.0	-	-	1.3
UZB*306*04	-	80	120	-	5.7*	4.4*	-	0.9	0.9
KAZ*181*00	-	-	100	-	-	4.7*	-	-	1.4
CKZ-240-03	-	80	-	-	13.6	-	-	1.1	-
EKZ-047-05	40	40	-	8.7	5.8*	-	1.1	-.4	-
EKZ-204-01	-	80	-	-	95.2	-	-	1.2	-

	LOT	LRV	LPR
MEAN SNNR IMPROVEMENT =	0.72	1.01	0.90
STANDARD DEVIATION =	0.62	0.53	0.97
NUMBER OF EVENTS =	10	12	10

TABLE V-1

CHIRP MATCHED FILTER IMPROVEMENT IN SIGNAL+NOISE/NOISE RATIO
(PAGE 12 OF 16)

REGION 'TAI' - TAIWAN, S RYUKYU ISLANDS, EAST CHINA SEA

EVENT	CHIRP LENGTH			BANDPASSED SNNR			SNNR IMP (DB)		
	LOT	LRV	LPR	LOT	LRV	LPR	LOT	LRV	LRR
CHI*028*04	230	700	700	11.3	7.5	6.9	1.8	0.0	2.2
RYU*155*02	300	500	500	108.3	101.7	66.5	1.2	3.6	5.0
RYU*197*02	240	520	520	24.2	48.0	34.1	3.1	3.0	3.6
RYU*209*16	360	640	640	261.4	106.8	68.5	2.9	3.9	1.3
TAI*004*05	500*	1000	-	5.0*	3.2*	-	2.9	1.8	-
TAI*004*12	280	600	600	97.9	64.0	50.2	4.5	1.5	3.1
TAI*006*06	200	600	600	19.7	10.5	13.5	3.1	0.1	-.9
TAI*010*05	700	800	800	50.6	20.0	17.7	0.2	4.9	3.8
TAI*178*08	300	500	500	158.7	94.8	81.4	2.3	4.2	4.3
TAI*182*18	200	500	500	548.8	153.3	80.1	4.7	0.8	2.4
TAI*195*23	300	-	-	20.1	-	-	6.0	-	-
TAI*198*13	300	400	400	30.0	55.8	26.4	3.6	3.8	4.1
RYU*231*18	310	730	730	23.8	20.8	6.5	2.1	1.6	1.1
TAI*235*21	250	-	-	73.9	-	-	2.9	-	-
TAI*312*06	340	440	440	181.8	76.1	74.9	4.1	5.5	5.9
TAI*320*03	220	260	260	34.3	35.8	36.5	3.3	2.3	1.7
TAI*326*02	220	440	380	189.6	58.1	57.9	4.4	5.6	5.4
HON*306*06	340	260	260	14.4	20.4	16.1	2.2	2.6	3.5

	LOT	LRV	LRR
MEAN SNNR IMPROVEMENT =	3.09	2.91	3.11
STANDARD DEVIATION =	1.42	1.83	1.84
NUMBER OF EVENTS =	17	15	15

TABLE V-1

CHIRP MATCHED FILTER IMPROVEMENT IN SIGNAL+NOISE/NOISE RATIO
(PAGE 13 OF 16)

REGION 'KUR' - KURILE ISLANDS FROM JAPAN TO KAMCHATKA

EVENT	CHIRP LENGTH			BANDPASSED SNNR			SNNR IMP (DB)		
	LOT	LRV	LPR	LOT	LRV	LPR	LOT	LRV	LPR
KUR/135/21	828	806	806	0.0	0.0	0.0	-.6	4.8	4.1
KUR/146/01	566	762	762	0.0	0.0	0.0	5.7	6.9	6.2
KUR/147/16	479	828	828	0.0	0.0	0.0	6.3	4.8	7.1
KUR/152/21	566	697	697	0.0	0.0	0.0	2.7	5.9	4.9
KUR/190/16	928	1002	1002	0.0	0.0	0.0	6.9	4.4	4.6
KUR/191/03	741	958	958	0.0	0.0	0.0	6.2	4.0	7.2
KUR/191/09	523	871	871	0.0*	0.0*	0.0*	0.5	0.8	0.5
KUR/213/02	459	893	893	0.0	0.0	0.0	4.7	8.7	7.9
KAM*078*18	980	-	-	3.6*	-	-	1.8	-	-
KUR*001*16	700	-	-	3.4*	-	-	1.2	-	-
KUR*001*18	-	700	-	-	4.5*	-	-	0.0	-
KUR*005*02	700	900	900	4.7*	4.7*	3.6*	2.6	6.1	5.2
KUR*009*14	-	-	900	-	-	2.2*	-	-	2.0
KUR*022*01	-	700	1150	-	3.5*	4.4*	-	1.0	0.0
KUR*028*23	980	-	-	3.4*	-	-	-4.3	-	-
KUR*046*16	860	850	850	3.4*	4.8*	2.9*	0.5	5.0	[illegible]
KUR*049*18	860	850	850	4.2*	4.9*	3.8*	3.8	-.8	1.7
KUR*054*03	620	1000	1000	36.8	26.6	23.3	2.9	0.7	0.3
KUR*054*27	740	1000	1000	25.0	19.6	16.9	3.8	2.2	2.7
KUR*054*37	620	1000	1000	30.7	24.4	21.7	3.1	1.1	0.9
KUR*055*10	980	1000	1000	46.7	134.4	90.4	3.5	5.7	5.7
KUR*056*22	620	700	700	3.5*	4.0*	3.7*	1.8	-1.5	0.3
KUR*057*02	980	700	700	46.6	132.5	102.1	2.7	1.8	0.6
KUR*057*05	980	850	850	6.8	7.4	6.6	3.4	7.1	7.9
KUR*063*23	740	1000	1000	4.5*	11.8	6.4	3.0	6.1	10.8
KUR*070*06	620	850	-	3.5*	3.0*	-	2.3	1.8	-
KUR*077*07	980	-	-	11.4	-	-	4.6	-	-
KUR*153*00	500*	700	700	8.5	6.0*	6.6	3.6	4.2	3.2
KUR*169*19	740	1000	1300	11.2	10.7	5.7*	2.5	3.7	0.8
KUR*171*18	980	700	1150	14.3	20.7	9.2	0.2	0.6	3.9
KUR*171*22	-	1000	-	-	5.8*	-	-	3.7	-
KUR*190*21	500	850	1000	2.7*	5.0*	3.0*	3.9	1.6	4.5
KUR*193*06	-	850	-	-	51.1	-	-	7.0	-
KUR*194*00	860	950	1000	23.3	53.5	39.4	4.5	7.7	7.4
KUR*195*15	500	700	700	4.8*	9.9	6.5	4.7	4.7	2.7

TABLE V-1

CHIRP MATCHED FILTER IMPROVEMENT IN SIGNAL+NOISE/NOISE RATIO
(PAGE 14 OF 16)

REGION 'KUR' - KURILE ISLANDS FROM JAPAN TO KAMCHATKA

EVENT	CHIRP LENGTH LOT	CHIRP LENGTH LRV	CHIRP LENGTH LRR	BANDPASSED SNNR LOT	BANDPASSED SNNR LRV	BANDPASSED SNNR LRR	SNNR IMP (DB) LOT	SNNR IMP (DB) LRV	SNNR IMP (DB) LRR
KUR*211*21	500	700	700	55.6	81.1	34.6	2.4	1.7	2.8
KUR*216*02	500	850	850	10.0	14.7	11.8	1.8	8.0	7.2
KUR*217*17	720	980	980	188.6	205.8	128.0	2.0	7.9	6.3
KUR*226*11	940	980	-	4.5*	6.6	-	1.0	4.3	-
KUR*229*19	830	1120	1120	3.3*	3.6*	3.1*	1.5	2.7	3.0
KUR*231*21	-	850	-	-	10.5	-	-	6.8	-
KUR*232*17	500	840	980	16.1	12.3	10.3	5.6	6.6	1.7
KUR*232*21	610	-	-	3.3*	-	-	3.4	-	-
KUR*232*23	720	980	980	82.5	66.6	46.8	3.5	3.0	3.1
KUR*235*03	-	1120	-	-	7.9	-	-	1.6	-
KUR*236*10	720	980	980	5.3*	4.0*	5.1*	-1.1	6.8	1.1
KUR*306*16	500	700	700	21.4	21.0	9.9	5.5	4.5	4.7
KUR*311*16	-	700	-	-	11.2	-	-	4.1	-
KUR*318*01	610	-	-	4.1*	-	-	0.4	-	-
KUR*322*15	500	-	-	4.2*	-	-	-.8	-	-
KUR*322*17	830	990	-	3.1*	3.2*	-	0.9	0.8	-
KUR*323*17	720	700	700	5.2*	5.8*	4.2*	-.6	3.7	5.1

	LOT	LRV	LRR
MEAN SNNR IMPROVEMENT =	3.65	4.71	4.73
STANDARD DEVIATION =	1.91	2.38	2.69
NUMBER OF EVENTS =	23	29	24

TABLE V-1

CHIRP MATCHED FILTER IMPROVEMENT IN SIGNAL+NOISE/NOISE RATIO
(PAGE 15 OF 16)

REGION 'KAM' - KAMCHATKA PENINSULA, KOMANDORSKY ISLANDS

EVENT	CHIRP LENGTH LOT	CHIRP LENGTH LRV	CHIRP LENGTH LRP	BANDPASSED SNNR LOT	BANDPASSED SNNR LRV	BANDPASSED SNNR LRP	SNNR IMP (DB) LOT	SNNR IMP (DB) LRV	SNNR IMP (DB) LRP
KAM/166/14	610	1046	1046	0.0	0.0	0.0	-.1	1.3	0.8
KOM/148/10	523	697	697	0.0	0.0	0.0	0.0	4.6	5.2
KAM*003*06	560	700	700	12.5	16.5	14.3	5.3	2.0	3.6
KAM*003*19	700	-	-	3.5*	-	-	0.8	-	-
KAM*004*02	600	900	800	3.6*	3.0*	2.7*	-1.2	2.3	2.1
KAM*005*16	620	850	850	3.6*	2.4*	3.7*	3.7	1.8	-.2
KAM*009*14	620	-	-	3.7*	-	-	-1.1	-	-
KAM*012*20	500	1050	1200	15.1	13.3	11.2	2.4	1.4	4.6
KAM*042*21	740	1000	850	6.6	6.2	6.9	-.2	2.0	-1.6
KAM*052*22	-	1000	-	-	3.9*	-	-	2.9	-
KAM*156*07	-	1150	-	-	5.3*	-	-	1.4	-
KAM*157*04	620	1300	700	8.2	8.3	6.1	2.6	0.5	1.8
KAM*163*14	-	1000	-	-	5.6*	-	-	0.3	-
KAM*177*17	620	1150	-	9.1	5.6*	-	3.3	4.1	-
KAM*180*14	-	1300	1000	-	3.3*	6.0	-	1.8	0.4
KAM*186*13	-	850	-	-	4.0*	-	-	4.4	-
KAM*189*05	-	1300	-	-	3.2*	-	-	5.9	-
KAM*193*08	500	-	-	4.0*	-	-	2.7	-	-
KAM*197*13	-	1000	-	-	3.2*	-	-	1.3	-
KAM*206*13	-	700	700	-	8.2	6.4	-	2.2	2.3
KOM*044*22	740	700	700	3.3*	2.7*	3.2*	3.0	2.2	2.3
KOM*153*21	980	700	700	6.3	5.9*	6.1	-1.4	2.7	2.7
KUR*209*00	500	1150	1150	104.4	98.1	68.8	6.1	1.9	3.4
KAM*216*03	610	700	700	14.0	4.6*	10.1	1.5	4.9	0.9
KAM*216*12	610	700	700	73.0	120.5	50.5	2.1	4.9	5.7
KAM*231*19	500	850	850	13.3	22.7	5.2*	2.3	1.6	1.0
KAM*233*08	610	840	700	62.6	54.1	31.4	0.8	5.3	5.0
KAM*317*02	500	700	840	108.4	57.6	39.4	2.7	2.8	1.6
KAM*331*14	610	840	840	28.7	19.3	22.4	0.3	4.2	4.2
KAM*332*21	610	980	1120	31.4	19.4	16.5	3.0	2.0	3.4
KOM*229*08	-	980	-	-	3.1*	-	-	2.2	-
KOM*229*10	-	700	980	-	5.3*	4.8*	-	1.9	2.0
MEAN SNNR IMPROVEMENT =							1.92	2.63	2.81
STANDARD DEVIATION =							2.02	1.52	2.13
NUMBER OF EVENTS =							16	14	16

CHIRP MATCHED FILTER IMPROVEMENT IN SIGNAL+NOISE/NOISE RATIO
(PAGE 16 OF 16)

REGION 'OTHER' - OTHER EVENTS NOT GROUPED

EVENT	CHIRP LENGTH			BANDPASSED SNNR			SNNR IMP (DB)		
	LQT	LRV	LRR	LQT	LRV	LRR	LQT	LRV	LRR
UAR*180*09	300	460	460	155.6	78.0	99.3	-.3	5.9	4.7
ARA*333*10	190	440	440	26.0	45.1	26.1	0.9	3.9	4.3
CAR*324*07	160	440	440	53.0	99.0	113.2	0.1	1.0	0.7
IRA*319*19	100	320	320	10.7	9.8	7.5	-.1	1.5	1.9
CHI/156/10	183	348	348	0.0	0.0	0.0	3.4	2.2	2.0
CHI/249/21	392	784	784	0.0	0.0*	0.0*	2.1	2.7	2.5
CHI*030*03	150	300	360	16.8	27.8	9.8	2.0	1.5	0.9
KAM*051*20	-	850	850	-	2.8*	3.1*	-	2.9	-.3
LOM*157*19	320	160	160	15.2	33.3	29.2	2.2	2.4	2.6
NRS*058*10	220	250*	250*	41.3	92.3	63.7	3.9	0.4	1.4
NRS*059*17	220	300	300	4.3*	7.6	6.2	3.1	0.6	1.5
RYU*196*18	-	880	880	-	3.2*	3.2*	-	2.4	0.4
CRS*244*14	-	160	160	-	100.6	88.6	-	3.3	3.9
FRS/165/13	174	392	392	0.0	0.0	0.0	4.7	1.0	1.1
FRS/266/21	152	305	305	0.0*	0.0	0.0*	2.8	-.6	0.6
BKL*035*03	200	300	300	3.7*	3.9*	3.6*	2.1	1.1	0.2
RAI*222*19	180	150	150	73.9	199.3	86.6	-1.4	-.8	2.6
FRS*015*18	200	300	300	20.6	13.5	12.1	3.9	0.5	0.8
FRS*172*09	400	-	-	8.7	-	-	-.7	-	-
FRS*222*20	200	300	-	93.8	24.2	-	2.3	0.5	-
FRS*316*13	150	350	-	4.3*	4.6*	-	3.2	0.3	-
FRS*330*13	150	200	200	78.0	33.7	37.2	4.1	2.4	2.1
SIB*238*04	150	400	-	3.5*	4.0*	-	-.4	2.7	-
SIB*013*17	400	800	800	167.8	366.1	283.3	1.4	5.6	4.4
SIB*014*03	900	600	600	3.3*	5.1*	5.0*	3.6	4.1	4.9
MEAN SNNR IMPROVEMENT =							1.77	1.92	2.39
STANDARD DEVIATION =							1.89	1.96	1.42
NUMBER OF EVENTS =							16	16	14

The number of events not detected on any bandpassed beam but detected with a chirp filter was 15 (out of 556) at ALPA and 13 (out of 515) at NORSAR. Ten of these 13 NORSAR events were from the Kurile-Kamchatka area. These regions tended to have larger chirp gains than the other regions, therefore this preference is not unexpected. The exclusion of these events from the detection threshold estimation would not change significantly the 90 percent detection threshold of this region but would appreciably raise the 50 percent detection threshold level. This is discussed further in Section VI.

SECTION VI

NORSAR LONG-PERIOD SURFACE WAVE DETECTION CAPABILITY

The detection history of the 517 events in the data base was used to estimate the NORSAR long-period surface wave incremental detection probability curve. Smoothed estimates of detection probabilities were obtained by a new method (Ringdal, 1974). This method models detection as a random Gaussian process and obtains maximum-likelihood estimates of the process parameters based on the experimental data at hand. For a detailed description of the theory and its limitations, and a derivation of the likelihood functions, the reader is referred to Ringdal (1974).

Detections were determined independently for each component except for the 1971 events where detections were assessed only on the vertical component.

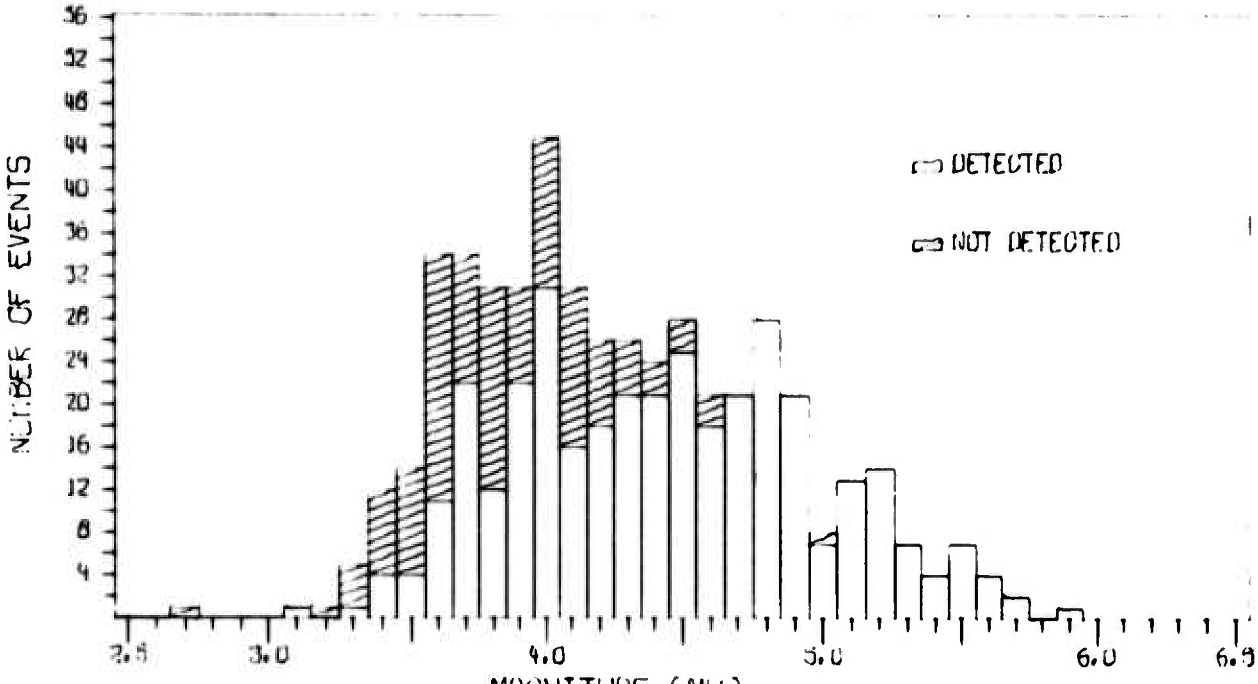
The criteria used to classify the events as detected or non-detected were:

- A peak on the bandpass or matched filtered trace, in a signal gate defined by a 4.0 km/sec arrival and a 2.5 km/sec arrival, which is 3 dB larger than any other peak within a 15 to 30 minute gate (depending on distance) centered at the peak.
- The peak and its code should show signal-like, i.e., dispersive characteristics.

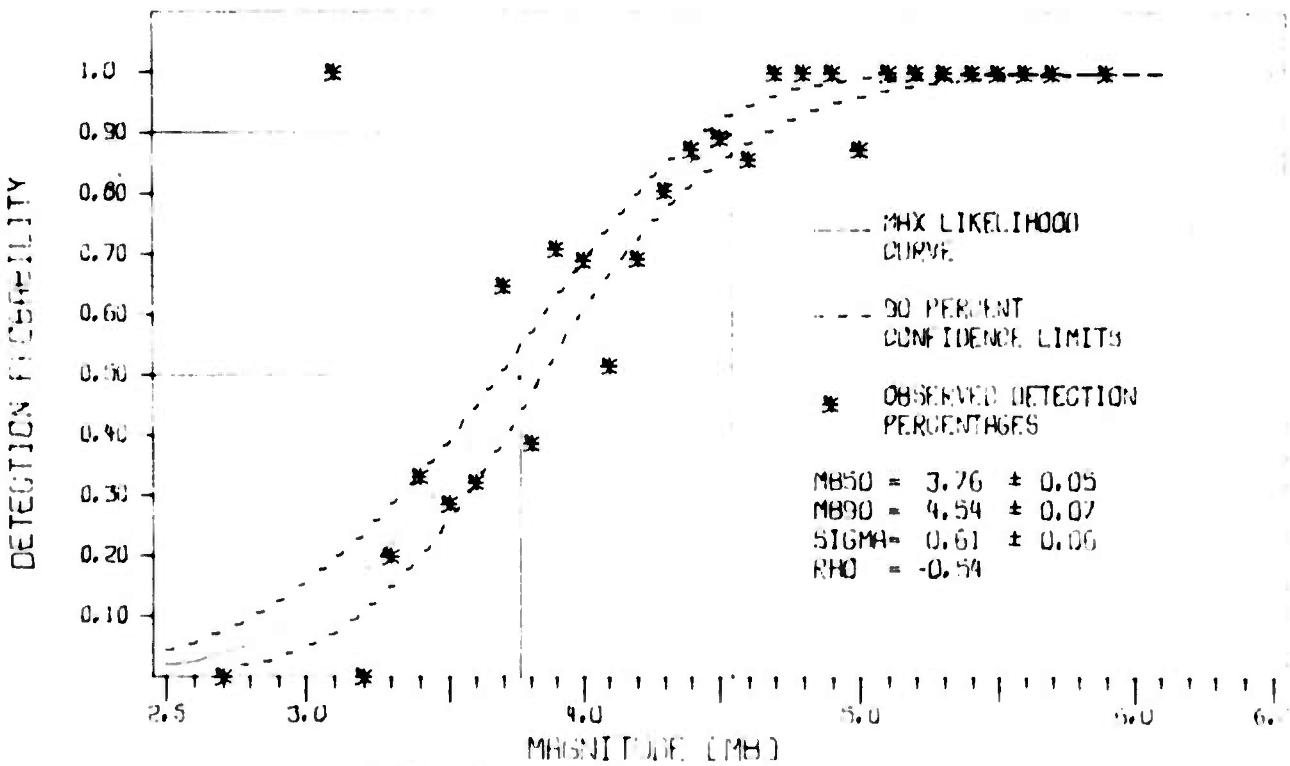
After an examination of a number of events from a particular region, the analyst gains an intuition for the output trace characteristics that play a major part in marginal detection cases. In most of the marginal detection/non-detection cases the judgment for detection was conservative with the result that the false alarm rate was low (estimated at less than 1 percent) and that the detection threshold was also conservative.

The subsets of events used for detection threshold estimation and their thresholds, based on the assumptions of the detection model, are:

- All earthquakes in Eurasia, Figure VI-1. The 90 percent detection threshold is at $m_b = 4.5$ which is the same as reported in Special Report No. 7 for NORSAR.
- Kurile-Kamchatka area, Figure VI-2. The 90 percent detection threshold is at $m_b = 4.5$ which is less than Special Report No. 7 but is 0.4 M_s units higher than ALPA. ALPA is substantially closer to this area, however, than NORSAR. This area also had the majority of chirp-filter-only detections. Although the 90 percent detection threshold is essentially unaffected by these events, the omission of the chirp filter detections would raise the 50 percent detection threshold level from $m_b = 3.9$ to about $m_b = 4.1$.
- Central Asia events, Figure VI-3. The 90 percent detection threshold is $m_b = 4.6$ which is greater than last reported. These set of events is different than the last report, however, as this set includes only events of short chirp lengths (≤ 250 seconds) of the Sinkiang, Tadzhik, Tibet, and China areas.



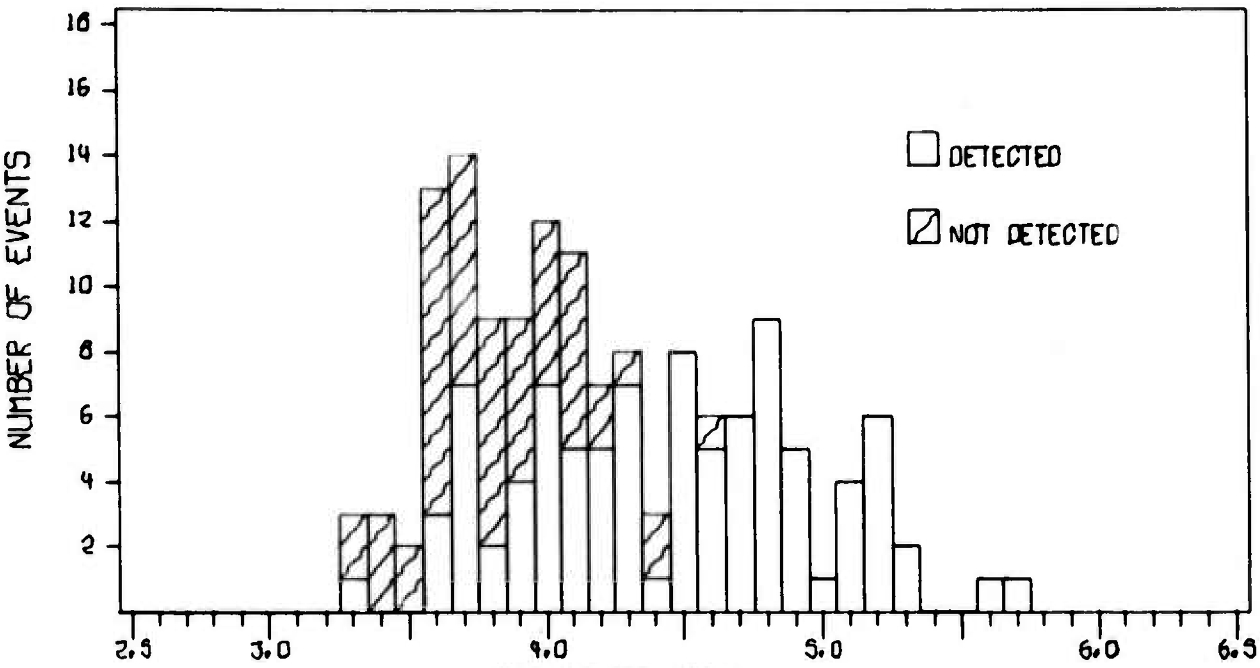
MB DISTRIBUTION OF PROCESSED EVENTS
ALL EARTHQUAKES



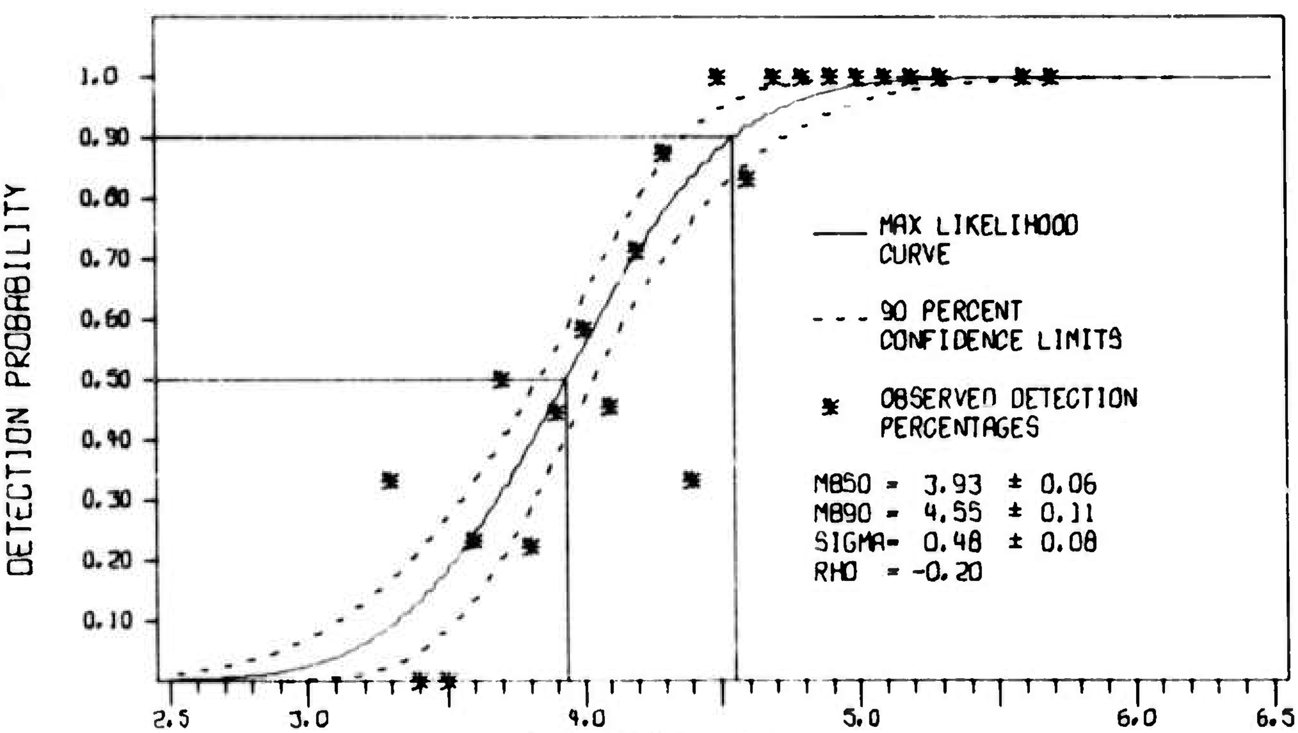
MAXIMUM LIKELIHOOD DETECTABILITY CURVE
ALL EARTHQUAKES

FIGURE VI-1

NORSAR LP SURFACE WAVE DETECTION STATISTICS
FOR ALL EARTHQUAKES 1971-1972



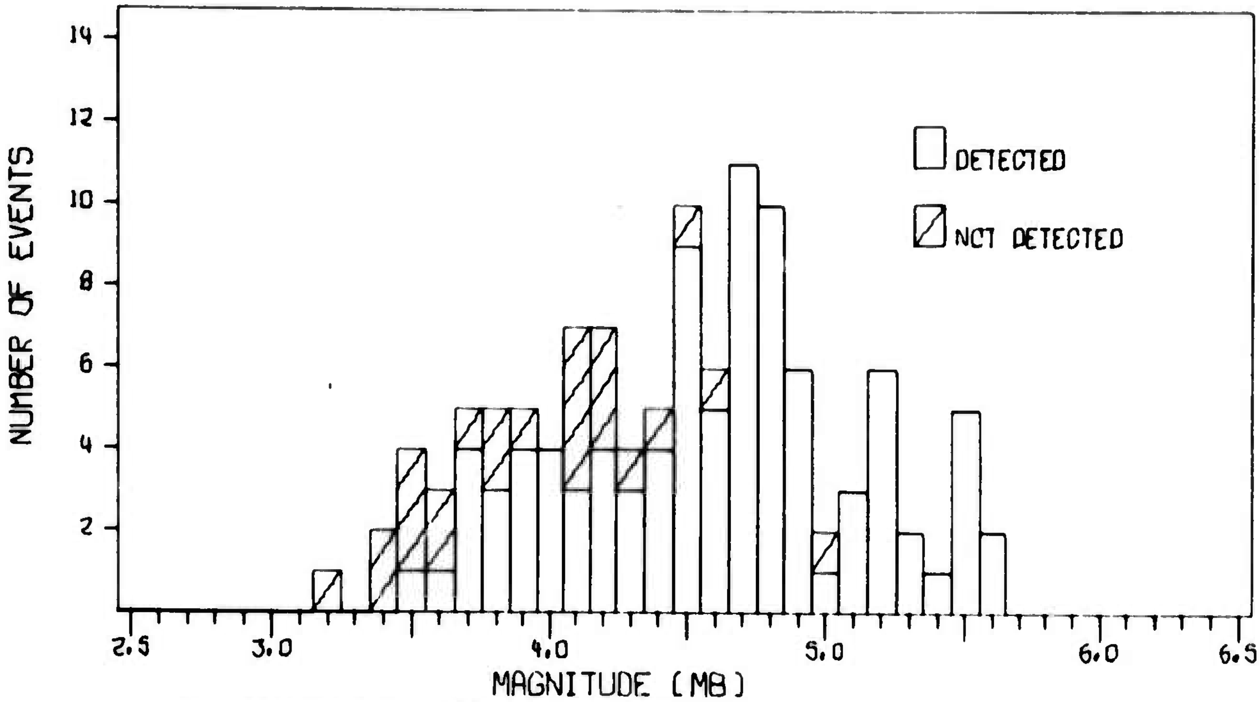
MB DISTRIBUTION OF PROCESSED EVENTS
KAMCHATKA-KURILE EVENTS



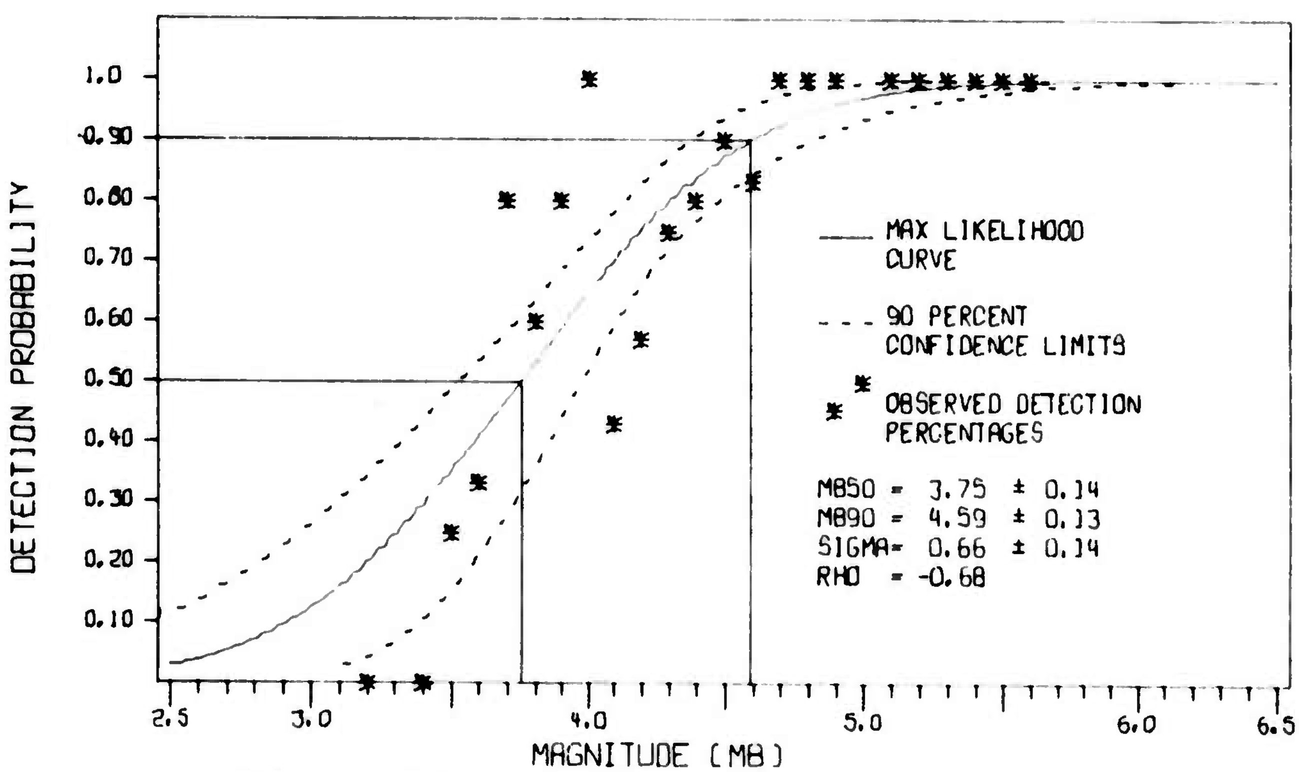
MAXIMUM LIKELIHOOD DETECTABILITY CURVE
KAMCHATKA-KURILE EVENTS

FIGURE VI-2

NORSAR LP SURFACE WAVE DETECTION STATISTICS
FOR THE KURILE-KAMCHATKA AREA



MB DISTRIBUTION OF PROCESSED EVENTS
CENTRAL ASIA EVENTS



MAXIMUM LIKELIHOOD DETECTABILITY CURVE
CENTRAL ASIA EVENTS

FIGURE VI-3

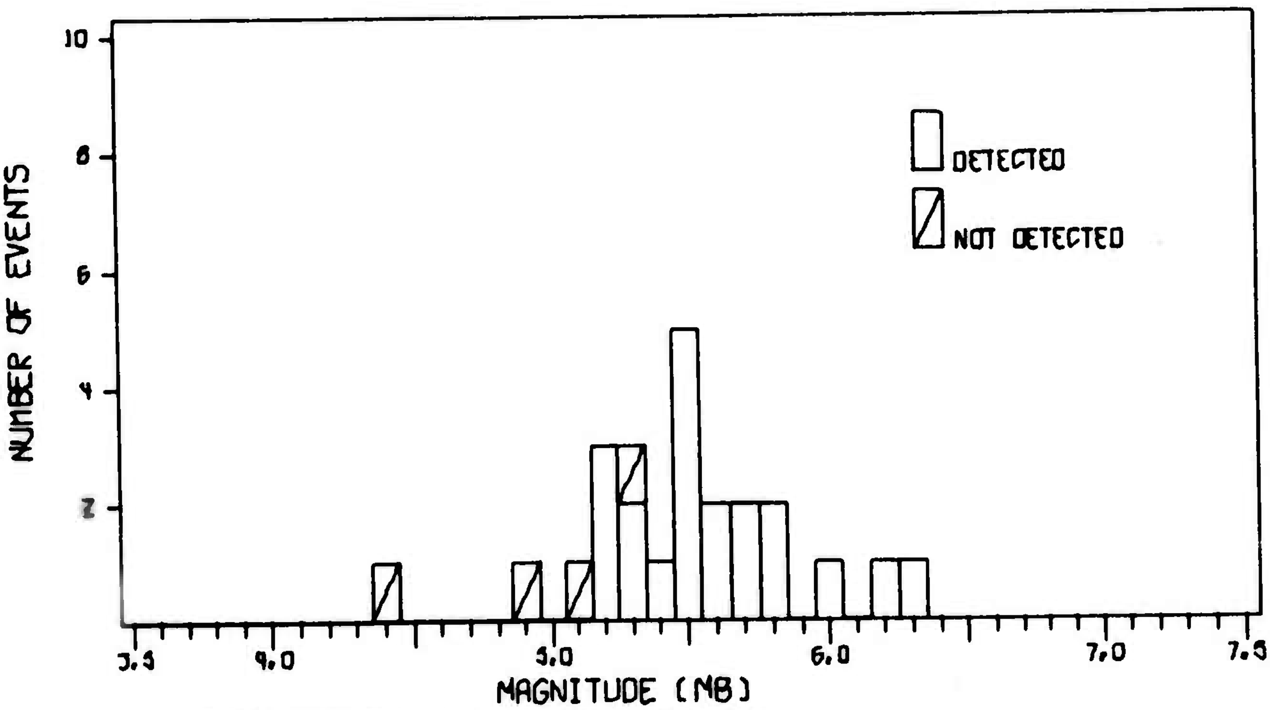
NORSAR LP SURFACE WAVE DETECTION STATISTICS
FOR THE CENTRAL ASIA AREA

Because of the number of points falling outside of the 90 percent confidence interval, this estimation is not as reliable as the two previous. The 90 percent detection threshold value at ALPA for this area is $m_b = 4.4$.

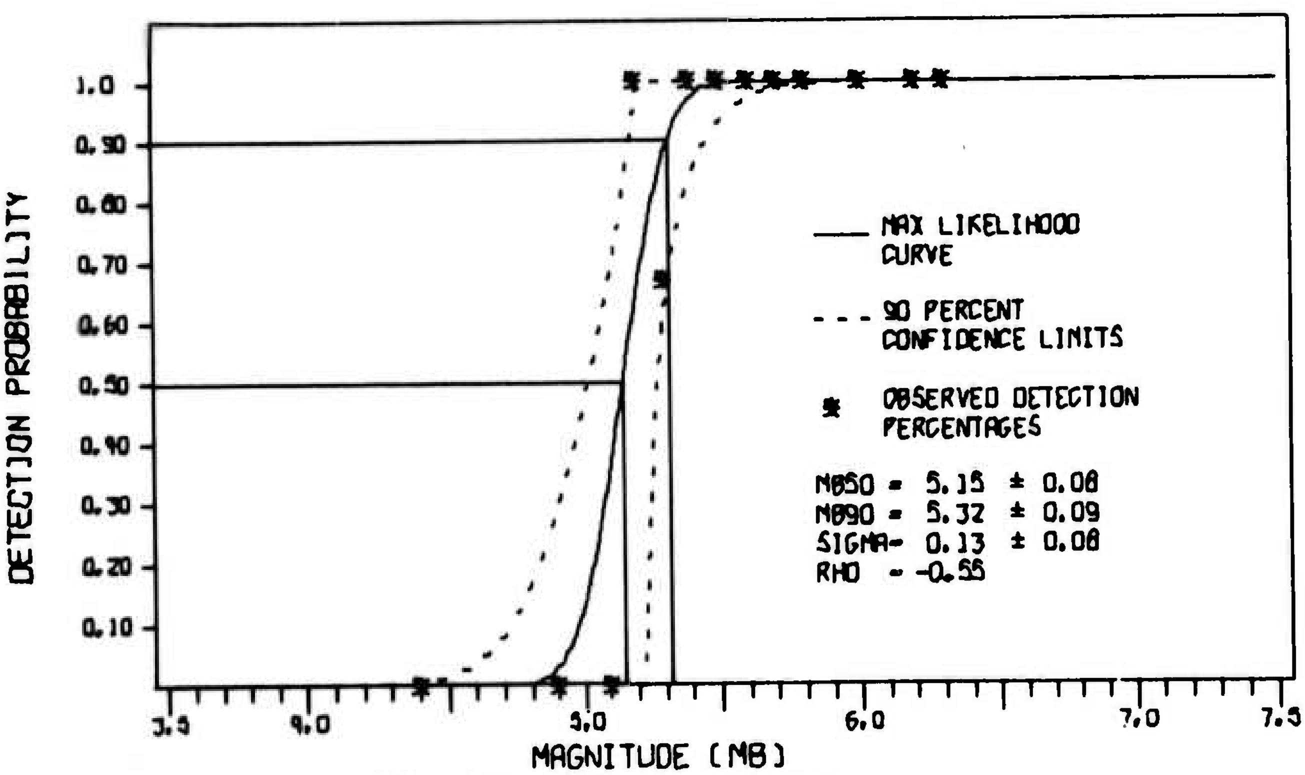
- Presumed explosions, Figure VI-4. The method of detection threshold estimation used here is subject to possible large errors when the number of events is small as in this set. Although the indicated 90 percent detection threshold is at $m_b = 5.3$ this estimate is highly unreliable.

- Winter and summer events, Figures VI-5 and VI-6 respectively. The winter 90 percent detection threshold is at $m_b = 4.5$ and the summer 90 percent detection threshold is at $m_b = 4.3$. These sets contain only the 1972 events. The summer threshold estimate is not as reliable as the winter estimate due primarily to the noise level. During the summer when the noise level is low, a small change in absolute noise level produces a large change in the equivalent surface wave magnitude of the noise. The winter detection threshold curve in contrast, has a steeper slope and narrower confidence limits, indicating a stable estimate of the detection threshold. Section IV of this report shows that an average of 3 to 4 dB improvement using MCF processing can be expected in the winter at NORSAR. This would be a change of 0.15 to 0.2 M_s units in the detection threshold at NORSAR in the winter.

The difference of 0.2 M_s units in the 90 percent detection thresholds for Central Asia events between NORSAR and ALPA seems unusual since NORSAR is 30° to 40° closer than ALPA to this region. This difference can be



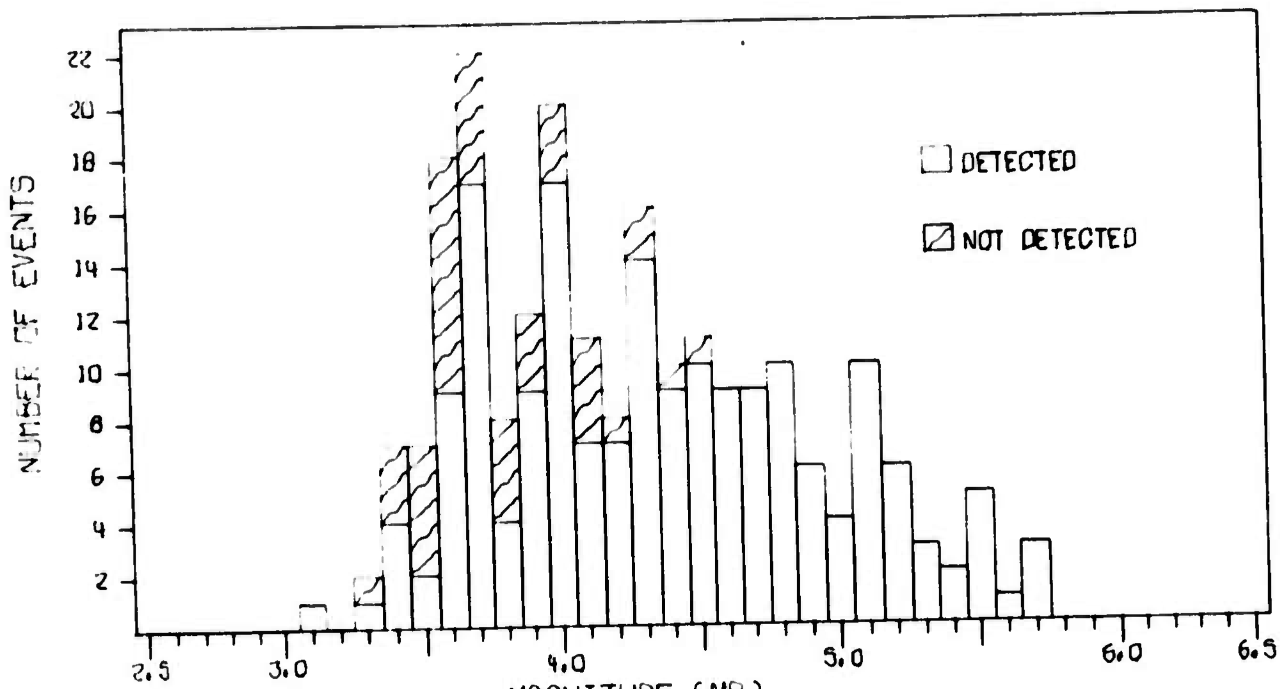
MB DISTRIBUTION OF PROCESSED EVENTS
PRESUMED EXPLOSIONS



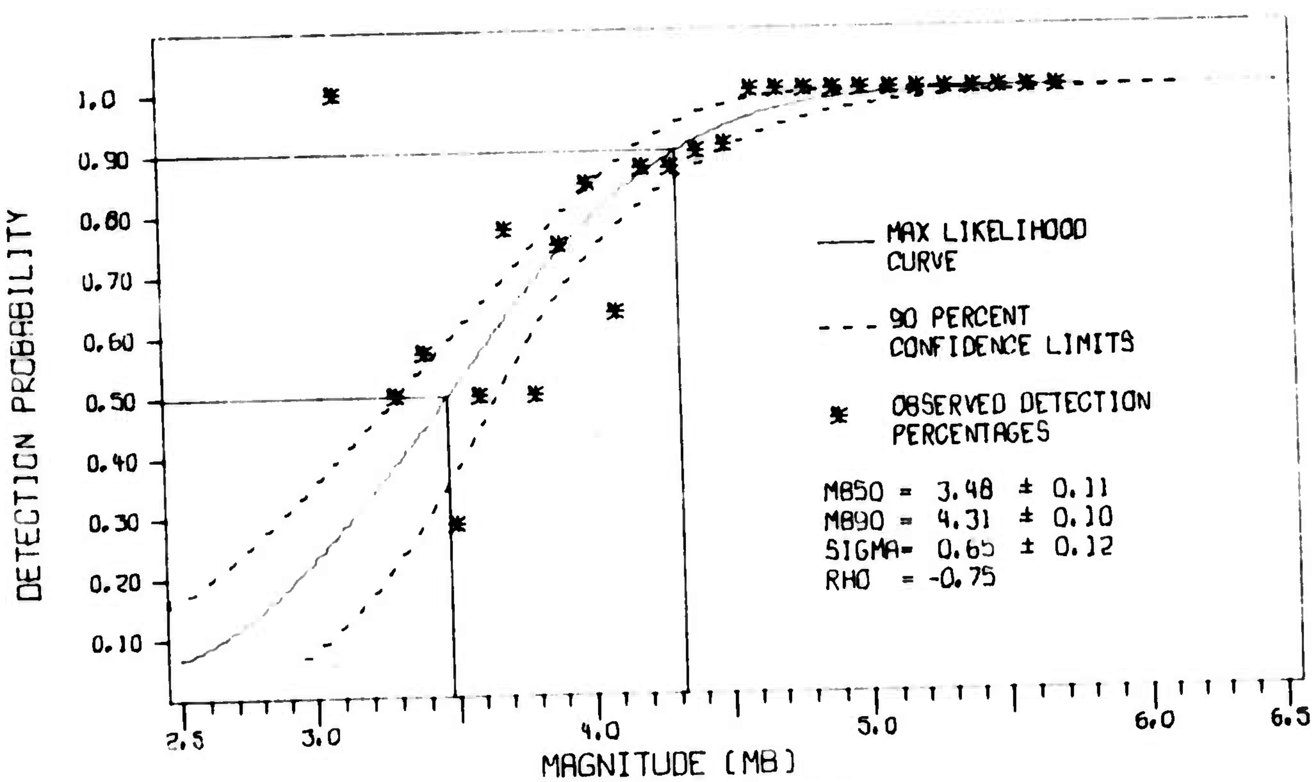
MAXIMUM LIKELIHOOD DETECTABILITY CURVE
PRESUMED EXPLOSIONS

FIGURE VI-4

NORSAR LP SURFACE WAVE DETECTION STATISTICS
FOR THE PRESUMED EXPLOSIONS



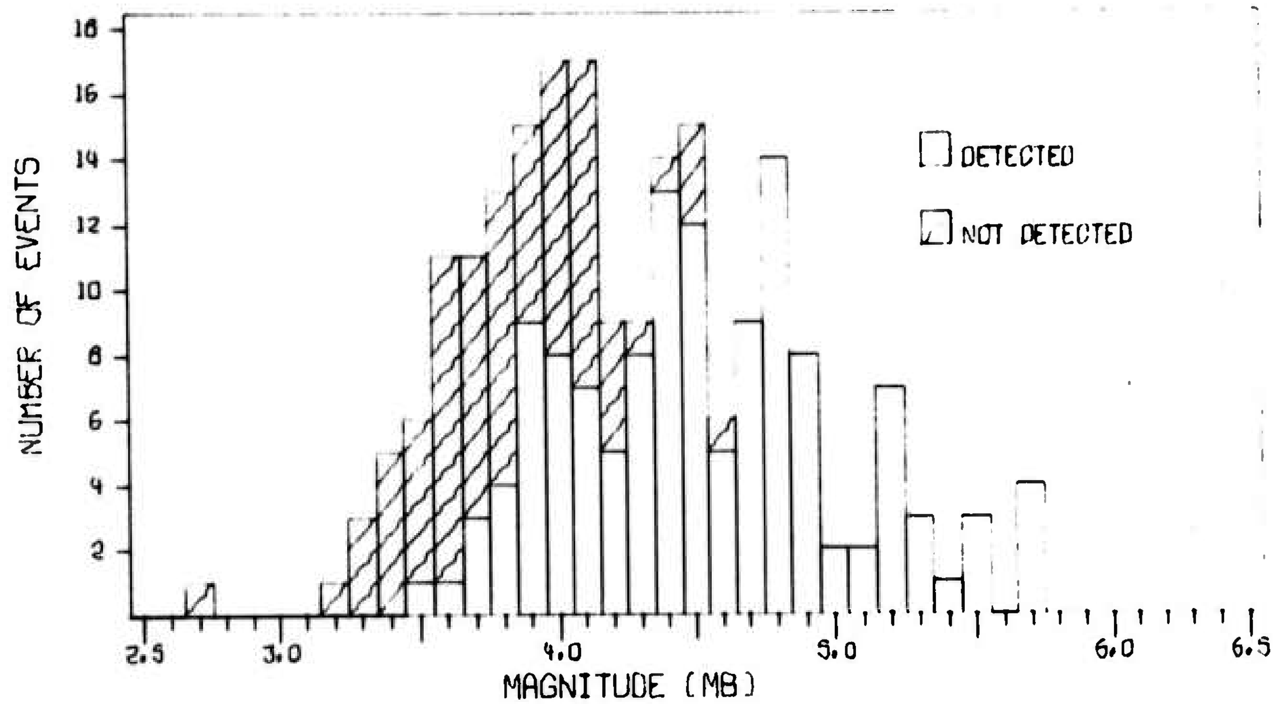
MB DISTRIBUTION OF PROCESSED EVENTS
SUMMER EVENTS



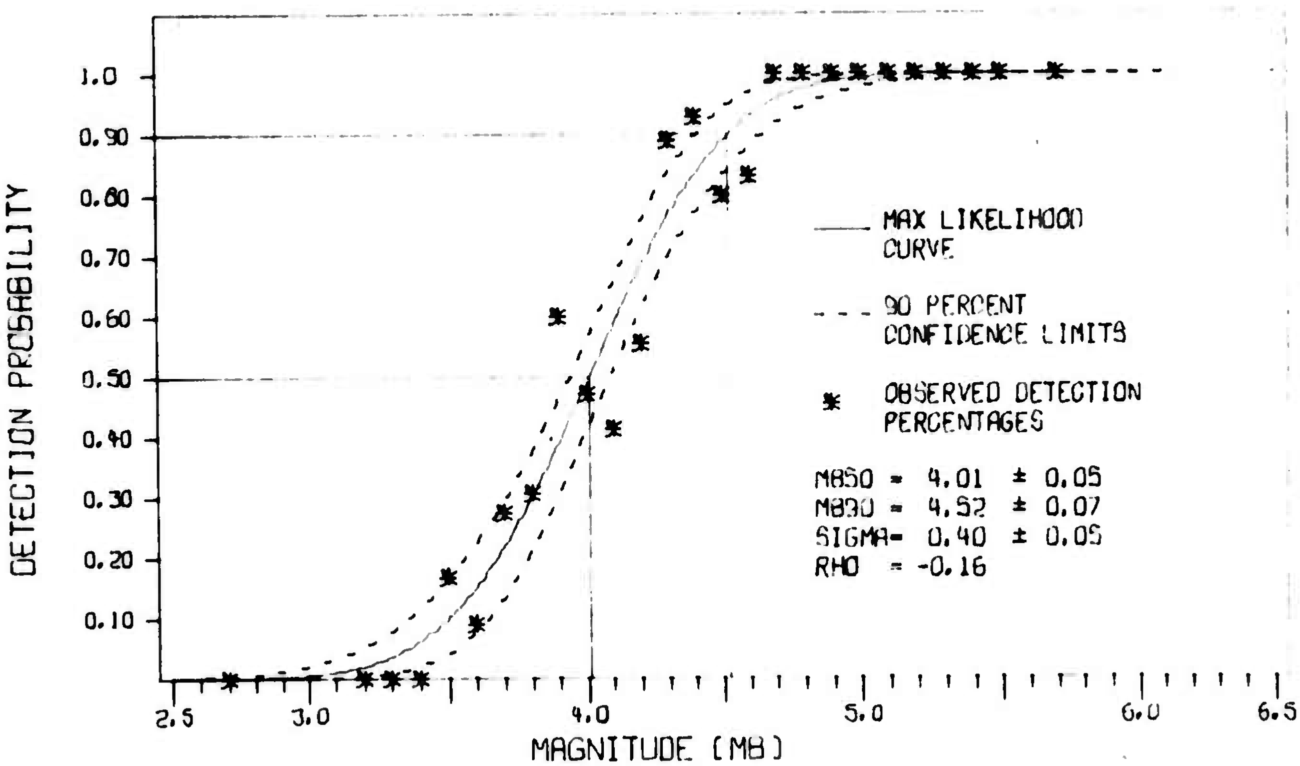
MAXIMUM LIKELIHOOD DETECTABILITY CURVE
SUMMER EVENTS

FIGURE VI-5

NORSAR LP SURFACE WAVE DETECTION STATISTICS
FOR THE SUMMER EARTHQUAKES



MB DISTRIBUTION OF PROCESSED EVENTS
WINTER EVENTS



MAXIMUM LIKELIHOOD DETECTABILITY CURVE
WINTER EVENTS

FIGURE VI-6

NORSAR LP SURFACE WAVE DETECTION STATISTICS
FOR WINTER EARTHQUAKES

explained by the spectra of the Central Asian signals (Eyres, 1972). The signal spectrum of the events in Central Asia at NORSAR tend to be strongest at the high end of the passband limit of 0.059 Hz which is also near the predominant microseismic peak. Thus by using the passband of 0.025 - 0.059 Hz, much of the signal energy of these events is rejected which in turn may raise their detection threshold. The spectra of these events at ALPA, however, do not contain as much higher frequency energy and thus are less attenuated by bandpass filtering.

SECTION VII

BEHAVIOR OF STANDARD DISCRIMINANTS

The three standard surface wave discriminants AL versus m_b AR versus m_b and M_s versus m_b were measured routinely from the three component bandpassed beams of the 381 detected events.

A. M_s - m_b MEASUREMENTS

The surface wave magnitude (M_s) was computed from the bandpassed beams by the following formulas:

$$M_s = \log \frac{A}{T} + 1.66 \log \Delta \qquad (\Delta \geq 25^o)$$

$$M_s = \log \frac{A}{T} + \log \Delta + 0.92 \qquad (\Delta < 25^o)$$

where A = maximum peak-to-peak amplitude of signal in millimicrons

T = period in seconds of cycle corresponding to A

Δ = epicentral distance in degrees

Figure VII-1 shows the vertical Rayleigh (LR) wave M_s versus m_b and Figure VII-2 shows the Love (LQ) wave M_s versus m_b. In both figures presumed explosions are plotted with an asterisk and earthquakes with a circle.

Complete separation between classes for this data set is obtained by the M_s-m_b discriminant for both Rayleigh and Love waves. The minimum

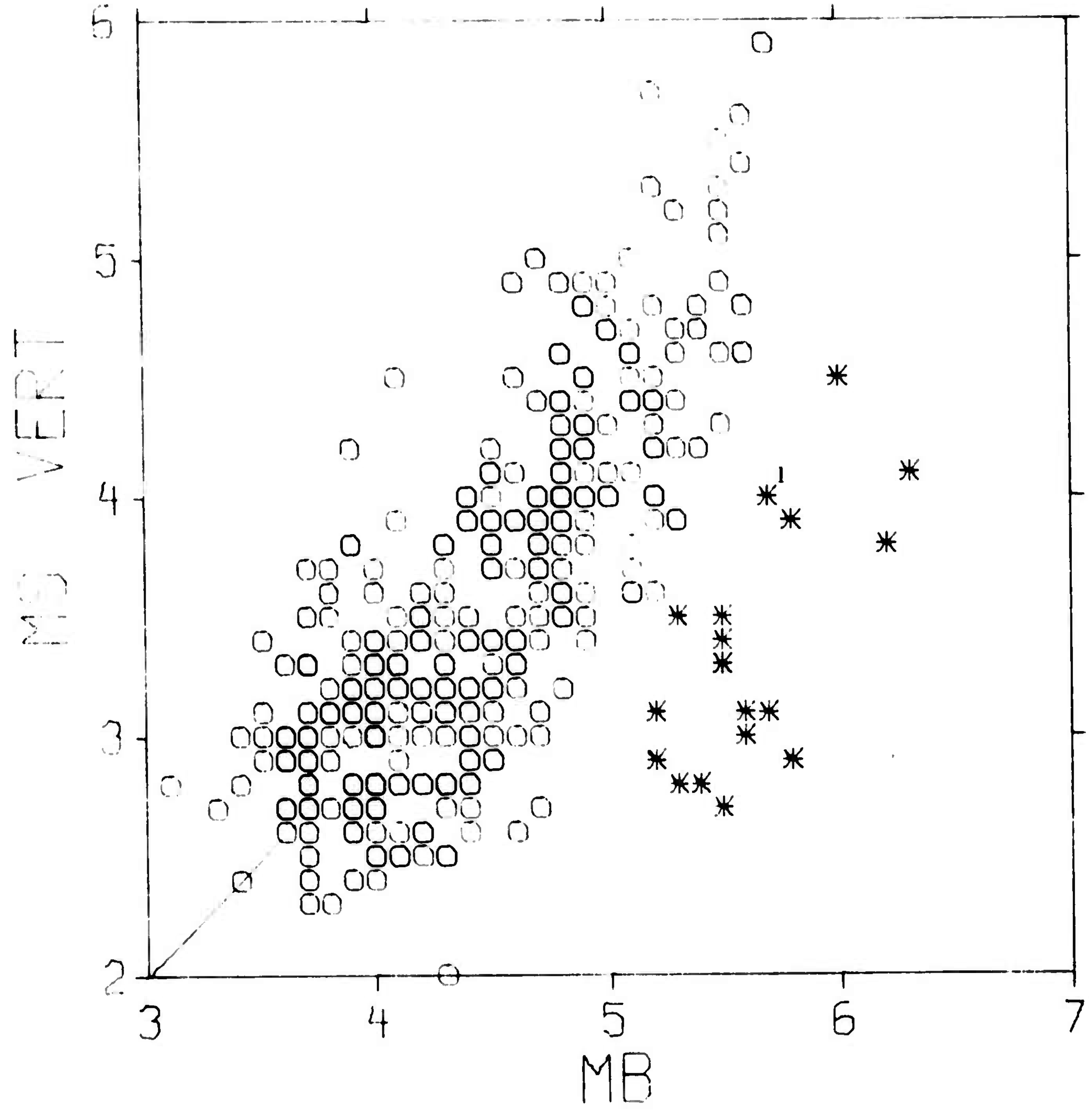


FIGURE VII-1

RAYLEIGH M_s - m_b PLOT FOR EVENTS

APRIL 1971 - NOVEMBER 1972

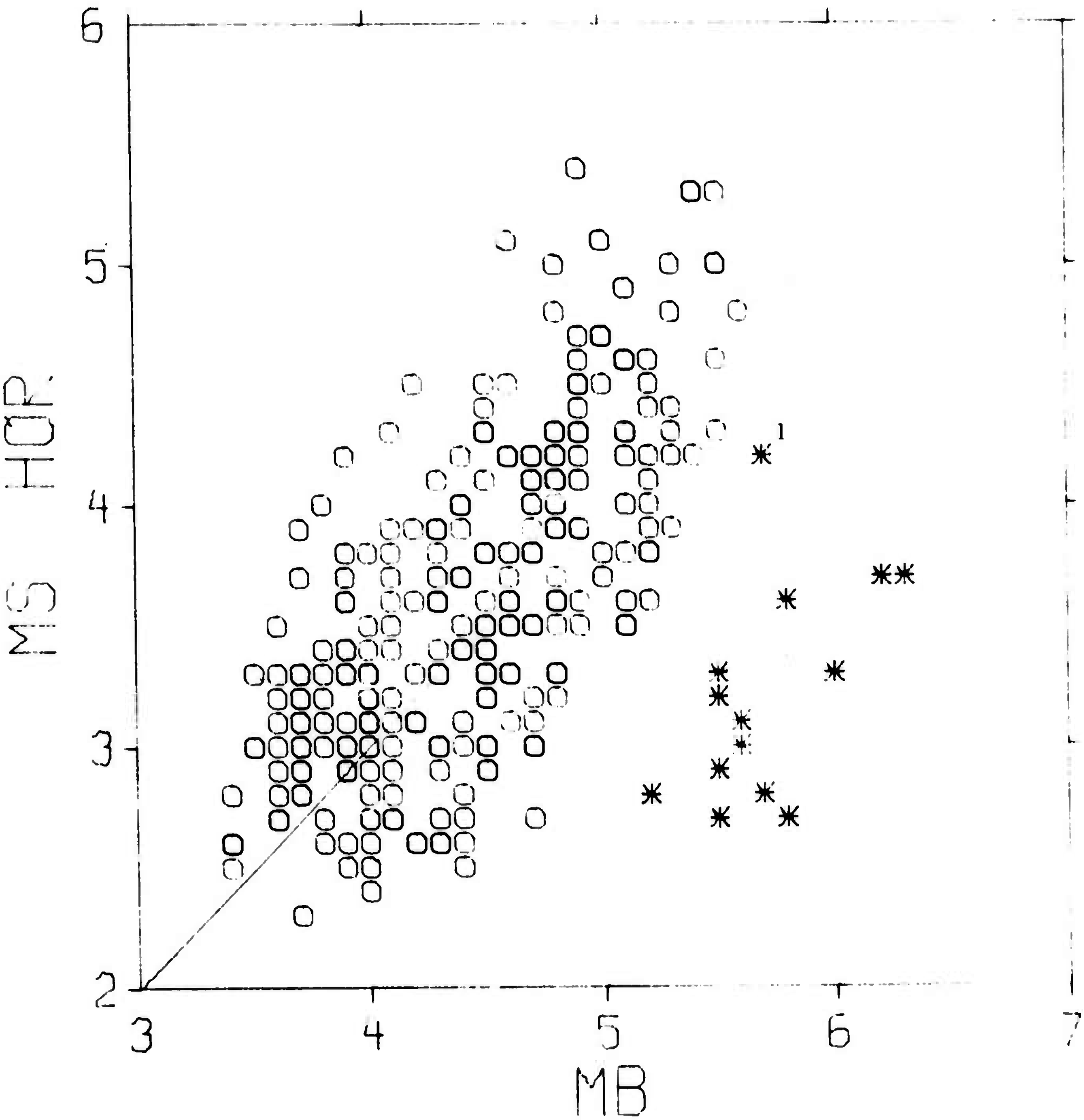


FIGURE VII-2

LOVE M_s - m_b PLOT FOR EVENTS

APRIL 1971 - NOVEMBER 1972

separation between earthquakes and presumed explosions having the same m_b is 0.3 M_s units for the LR vertical and 0.8 M_s units for the LQ.

These M_s - m_b results differ from those of Special Report No. 7 because not only have an additional 138 events been added, but Love wave M_s values have been computed for the 1971 presumed explosions. In addition, the eight events previously having poor separation have been reinvestigated and found to contain some mistakes in the M_s calculations and some incorrect m_b values.

The presumed explosion labeled '1' in Figure VII-2 is actually a double event (EKZ*345*04) and has a higher than expected M_s value. The "PDE" bulletin did not assign a magnitude to the second event thus we have used the m_b of the first event. Results from the short period NORSAR indicate that the second event is actually larger and is near m_b = 6.0 (Ringdal, 1973).

The earthquakes lying closest to the presumed explosion population were investigated for regional biases, radiation pattern effects or computation errors. In particular those events processed also at ALPA (Special Report No. 8) were used to corroborate the NORSAR M_s values.

There was no region which had consistently low M_s values. The events in common at NORSAR and ALPA with low M_s values had low M_s values at both arrays, except where a radiation pattern effect was obviously the cause, for example, as in YUG*243*00 which had M_s Rayleigh = 3.0 and M_s Love = 2.9 at ALPA and had M_s Rayleigh = 2.0 and M_s Love = 2.7 at NORSAR.

Four events with m_b values taken from the PDE bulletin caused some problems due to averages of a wide range of m_b values. For example, YUG*180*01 had an average m_b = 4.6 from four stations with $\Delta > 15^o$. The m_b values were 4.0, 4.1, 4.1, and 6.1 with the last value given by a station over 80^o away. Fortunately, these instances are rather rare. While we have uncritically used published m_b values, except for recomputing where possible

to include only teleseismic stations, we are aware that careful examination of the short period data would result in better m_b values and probably in better class separation. These problems are discussed in Texas Instruments Special Report No. 9, 1973.

B. AL-AR VERSUS m_b

The AR parameter was introduced by Brune, Espinosa and Oliver (1963) as a measure of the total Rayleigh wave energy. The AL parameter is the equivalent measure of the Love wave energy. Evernden (1969) has used these parameters to discriminate between earthquake and presumed explosions. Our AL-AR measurements were made from the bandpassed beams in a signal arrival gate corresponding to a velocity window of 4.0 to 2.5 km/sec and have been scaled (Harley, 1971) so as to permit a comparison with Evernden's results. The scaled AL-AR values were then normalized to a body-wave magnitude of 5.0 and a distance of 20^o (Brune, 1963).

Figures VII-3 and VII-4 show AR versus m_b and AL versus m_b respectively. In both figures the earthquakes are plotted as circles and the presumed explosions as asterisks. (The presumed explosion labeled 1 is the double event on December 10, 1972 (EKZ*345*04)).

Both AL and AR isolate the two populations with AL being slightly superior to AR. A straight line at AL = 8.0 would, with the exception of EKZ*345*04, give complete separation of populations. A line at AR = 12, the highest value of a presumed explosion, would include two earthquakes in the presumed explosion population. Recomputing AL and AR for EKZ*345*04 using an m_b = 6.0 would improve separation considerably, however. In the range above the estimated 50 percent detection threshold for presumed explosions m_b = 5.1, both of the discriminants are good.

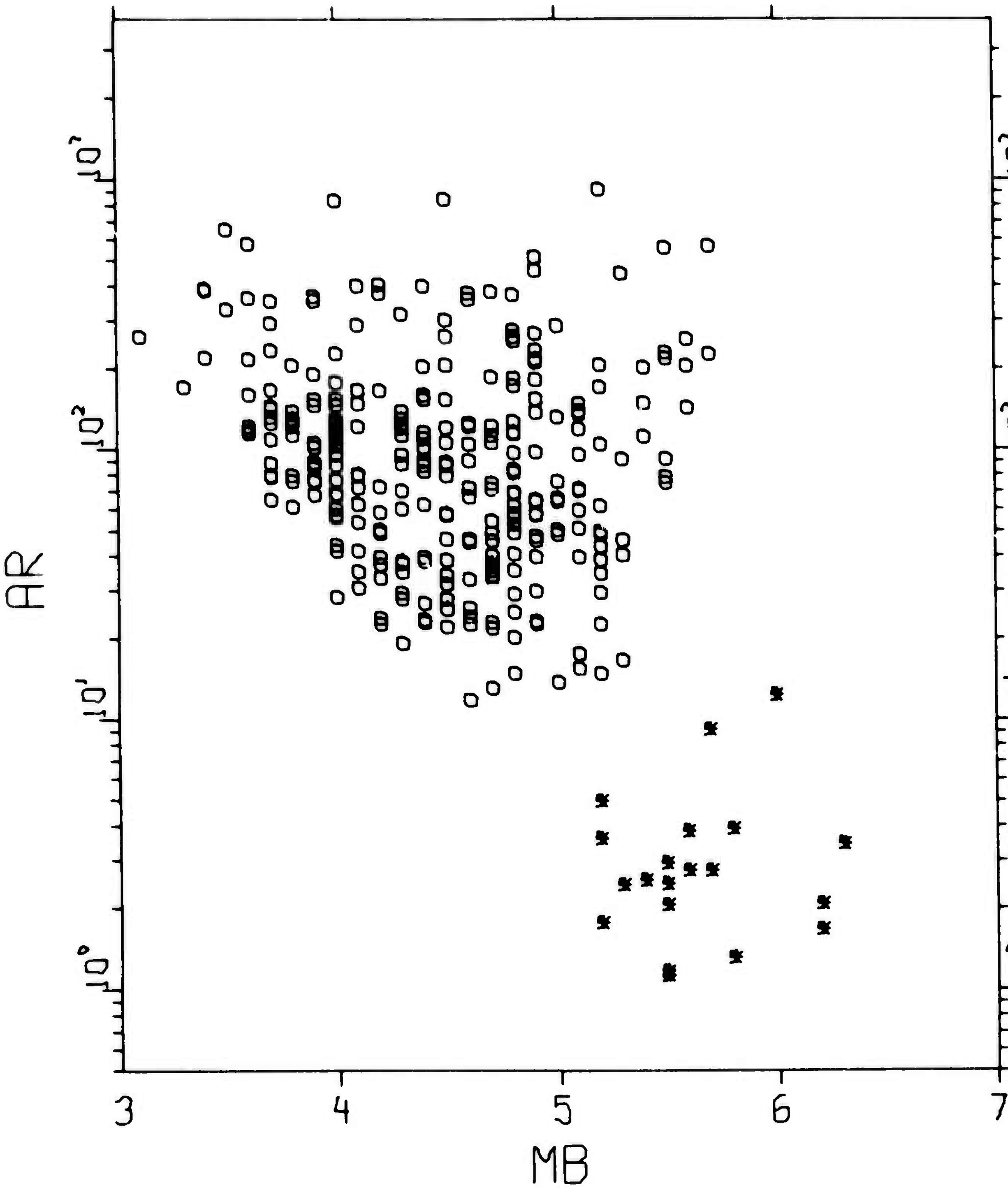


FIGURE VII-3

AR - m_b DISCRIMINANT

COMBINED 1971 AND 1972 EVENTS

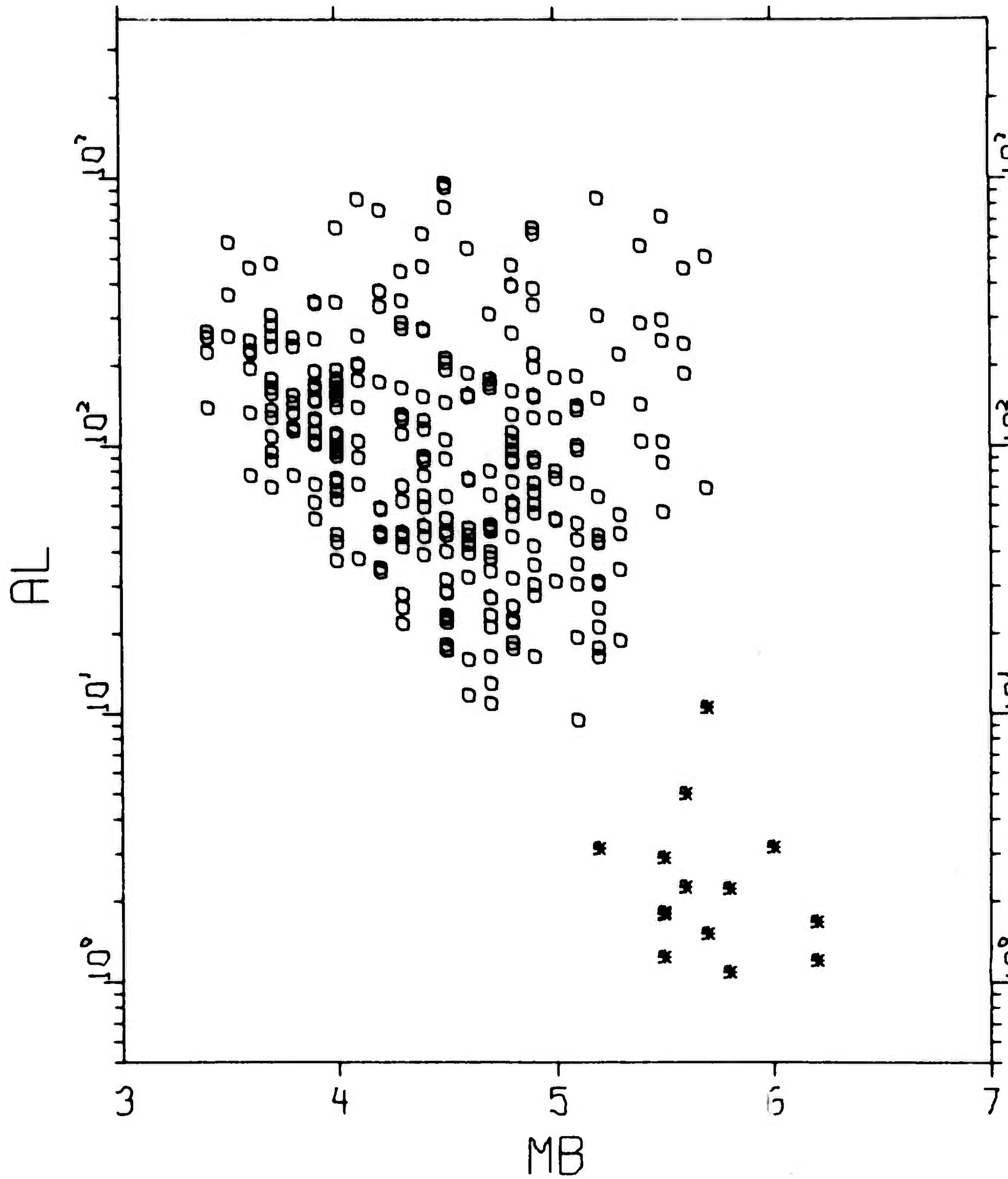


FIGURE VII-4

AL - m_b DISCRIMINANT

COMBINED 1971 AND 1972 EVENTS

In conclusion the measurements of M_s, AL and AR versus m_b provide good discrimination capabilities at NORSAR. In most cases. these discriminants would perform even better if better m_b estimates were available. Careful selection of available information with greater weight being given to the LASA and NORSAR values would be a direct approach to this problem.

SECTION VIII
CONCLUSIONS

A. MAJOR RESULTS

The major conclusions from the five studies of the NORSAR Long-Period Array Evaluation are summarized below. These conclusions are based on all the results obtained during the past two and one-half years.

1. Noise Analysis

- The noise level in the 20-40 second band is strongly seasonal. Summer levels (March to October) are around 7 mμ RMS and fairly constant. Winter noise is more erratic with levels varying from 8 to 15 mμ RMS. The maximum observed level was 79 mμ RMS.
- The high winter noise levels are caused by storms in the North Atlantic Ocean and many last from 12 to 36 hours. The noise generating mechanism is not understood.
- Noise directions are also seasonally dependent at NORSAR but are not strongly correlated with noise level. Winter noise tends to be strongly directional with preferred azimuths of 0^o, 250^o, and 280^o. Winter noise coherence is high at the frequencies of peak power. Summer noise is generally isotropic often with weak easterly direction and has low coherence particularly in the signal processing band of 17 to 40 seconds.

2. Signal Analysis

- Based on energy spectra, uncorrected for instrument response, the majority of the signal energy generally lies between periods of 17 to 40 seconds. Some Central Asian events, however, contain significant energy down to 13 seconds.

- The arrival azimuth of the signal is along the great circle path with only small deviations. Some events have shown shifts in arrival azimuth deep in the coda and at the higher frequencies.

- Signal similarity usually is very high along the propagation direction but degrades rapidly normal to the propagation path.

3. Array Processing Performance

a) Full Array

- Multichannel filter improvements in array gain are seasonally dependent for off-design noise in the signal band (0.025-0.059 Hz). The MCF averaged 4.0 dB more array gain than the beamsteer in winter noise conditions. This implies that the use of an MCF in winter could lower the detection threshold by 0.2 M_s units. Little gain improvement was obtained in the summer.

- Signal amplitude degradation of the beamsteer processor is 2.0 dB for the Rayleigh wave and 2.2 dB for the Love wave. The MCF signal degradation is slightly greater than the beamsteer for the samples used.

b) Reduced Array

- The high signal similarity over the reduced array significantly increased the performance of both the MCF and

beamsteer processors. For the 22 noise samples investigated, the MCF averaged 4 dB more noise suppression than the beamsteer processor.

- In contrast to the full array, the MCF improvement over the beamsteer is strongly correlated with the beamsteer noise level. The MCF improvement over the beamsteer for the reduced array is slightly less seasonally dependent than is the full array.

- The signal amplitude degradation for the beamsteer is 1.4 dB for the Rayleigh wave and 1.6 dB for the Love wave. These values are 0.6 dB less than for the full array. MCF signal loss is slightly more than the beamsteering loss.

c) MCF Processing Using One Noise Sample for MCF Design

- Using a single sample of summer noise for MCF design, array gain improvement of the MCF, when applied to events up to 15 days from that sample, showed no correlation with time separation.

4. Matched Filtering Performance

- Considerable effort was expended to determine the signal processing band. The 17-40 second period band (0.025-0.059 Hz) seemed to show slightly better overall performance than the other bands investigated and was adopted as the routine signal processing band for NORSAR.

- Chirp filter lengths were successfully used to regionalize the events. Chirp filters giving optimum SNNR improvements were found to have lengths which vary in a regular, consistent fashion over the Eurasian continent allowing contour maps of equal chirp length to be made.

- The SNNR improvements of the chirp filter averaged 2 dB more than the equivalent bandpass filter. For a given region, the standard deviations of the gains were typically 0.6 times the mean gain.

- Reference waveform filters (RWF) were not used on a routine basis at NORSAR. The marginally superior performance of the RWF did not seem worthwhile because chirp filters offered more stable and uniform results, were less sensitive to the presence of signal-like noise, and parametric values were simple to generate and determine.

- Chirp filters produced a small increase in the number of detected events at the 50 percent detection threshold level but did not materially affect the 90 percent detection threshold level.

5. Detection Threshold Estimation

- The 90 percent detection threshold (with a false alarm rate estimated at less than 1 percent) was estimated for the various event populations using a maximum likelihood method. Under the assumptions of this method, the 90 percent detection thresholds for the events studied here are:

  All Eurasian earthquakes $m_b = 4.5$

  Central Asia $m_b = 4.6$

  Presumed explosion $m_b = 5.1$ (this value is based on a few events and may be unreliable)

  Kurile-Kamchatka areas $m_b = 4.5$

  Summer events $m_b = 4.3$

  Winter events $m_b = 4.5$

- The difference between the summer and winter 90 percent detecion detection threshold is attributed to the increased noise level at NORSAR during the winter months.

6. Behavior of Standard Discriminants

- The M_s-m_b criteria achieved complete separation between event classes for both Rayleigh and Love waves.

- AL and Ar also achieved complete separation between classes and appear to give slightly better separation of classes than M_s-m_b at NORSAR. At ALPA the AL, AR versus m_b criteria performed more poorly than the M_s-m_b criterion.

B. SUGGESTIONS FOR FUTURE ANALYSIS OF NORSAR

The results from the NORSAR evaluation conducted during the past two-and-one-half years have pointed out areas which should be studied in any future analysis of NORSAR.

- The correlation of ambient noise level with the presence of winter storms in the North Atlantic ocean suggests two areas of investigation. First, the noise generation mechanism should be identified as either a coastal surf action, an interaction of deep water waves with continental shelves, or an open ocean mechanism. This would require fairly comprehensive wave and weather information from both Norway and England and possibly seismic data from English stations. Second, multichannel filters should be used on wintertime data. These may be fixed or possibly time-adaptive. If the first study demonstrates a structural effect, fixed MCF's may be useful for processing of winter data.

- More events from central Asia should be analyzed. Some areas show unusual behavior in both spectral content and dispersion,

particularly around the Caspian Sea, Tadzhik, and Kirgiz. These events tend to have particularly large high-frequency energy content, relatively wide dispersion, compared to Sinkiang, China, and more northerly areas, and occasionally reverse dispersion. It may be desirable to use wider processing bandwidths for central Asian events.

- Chirp matched filters should be evolved to more sophisticated non-linear models while maintaining simplicity. This may realize significantly higher signal-to-noise ratio gains for the central Asian events in particular.

- Maps of chirp filter length were successful in indicating seismic region boundaries. There is some evidence that the boundaries of the tectonic systems of Asia can be correlated with these maps. It may be possible that such maps, computed for several seismic stations, may be helpful in pointing out geologically interesting areas.

SECTION IX

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APPENDIX A

Table A-1 presents the entire ensemble of events processed during the evaluation of the NORSAR Long-Period Array. It includes 59 events from 1971 and 456 events from 1972. The latter group includes 133 new events processed since release of Special Report No. 7. Processing of the 1971 events was discussed in Special Report No. 5. A number of events previously included in the original 1971 and 1972 ensembles have been deleted. These are discussed in Appendix B.

The events are ordered chronologically and are identified by a name consisting of a three letter area code, the julian date, and the hour of origin. The year is indicated by the symbols separating the three parts. A "/" indicates 1971, a "*" indicates 1972, and a " - " indicates 1973*.

Other information includes the origin date and time, epicenter coordinates, delta and azimuth from NORSAR, m_b, Rayleigh and Love surface wave magnitudes, normalized AR and AL, depth (if reported), and coded comments. The latter consist of a letter indicating the source of event information, an "X' if the event is a presumed explosion, and the number of sites used to form the array beam. The source codes are "P" for the Preliminary Determination of Epicenters (PDE) bulletin of the National Oceanic and Atmospheric Administration, "L" for the Seismic Data Analysis Center bulletin for the LASA array, "N' for the NORSAR bulletin, and "I" or "J" for the Massachusetts

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* Note that these symbols are the same as used for the ALPA evaluation but are displaced by one year. That is, for ALPA, a " - " was used for the 1972 events, etc.

Institute of Technology - Lincoln Laboratory bulletin for the International Seismological Month (ISM) which was from 20 February to 19 March, 1972.

The events obtained from PDE, and those from the ISM group which were also listed by PDE were checked for m_b determination. Any m_b values reported by stations closer than 15 degrees to the event were deleted and the average m_b was recalculated. If a change in m_b resulted, an asterisk was placed next to the revised m_b.

Non-detection of a event on the Love or Rayleigh components is indicated by a dash in the M_s column; a "C" in those columns indicates detection by a chirp matched filter only. Love wave magnitudes of the 1971 events were computed only for the presumed explosions.

TABLE A-1

LIST OF EVENTS USED FOR EVALUATION
(PAGE 1 OF 21)

EVENT NAME	DATE	ORIGIN TIME	LATITUDE N/ LONGITUDE E	DELTA/ AZIMUTH	MB	MS RAY	MS LOVE	AP	AL	Z	NOTES
TIB/123/00	05/03	00.33.22	30.8/ 84.5	55.6/ 87.4	5.4	5.2	-	147	144	16	P (11)
TUR/126/04	05/06	04.24.34	39.0/ 29.7	24.9/143.3	4.6	4.4	-	-	-	N	P (18)
CAS/135/04	05/15	04.53.05	38.1/ 49.1	32.9/116.2	4.6	3.3	-	33	40	N	P (9)
KUR/135/21	05/15	21.03.46	43.4/147.3	69.9/ 32.2	4.7	4.1	-	72	41	48	P (9)
TUR/143/01	05/23	01.02.55	37.6/ 30.1	26.2/143.8	4.4	4.0	-	-	-	N	P (16)
FKZ/145/04	05/25	04.02.58	49.8/ 78.2	38.0/ 75.4	5.2	2.6	-	1.8	-	0	PX(16)
KUR/146/01	05/26	01.46.11	43.5/146.7	69.7/ 32.6	4.7	4.0	-	40	23	59	P (15)
TDZ/147/00	05/27	00.30.28	38.3/ 69.0	42.0/ 95.2	4.8	4.1	-	68	61	36	P (16)
KUR/147/16	05/27	16.50.31	43.8/146.4	69.3/ 32.7	5.2	4.4	-	22	25	36	P (11)
KOM/148/10	05/28	10.21.43	55.8/166.6	61.8/ 15.2	4.5	4.1	-	201	104	N	P (14)
KUR/152/21	06/01	21.20.27	43.6/150.2	70.4/ 30.1	4.6	3.5	-	25	11	N	P (11)
TIB/155/20	06/04	20.49.58	32.2/ 92.1	58.1/ 80.0	5.0	4.1	-	13	30	N	P (13)
CHI/156/10	06/05	10.21.28	37.3/113.7	63.7/ 59.9	4.7	5.0	-	186	316	N	P (15)
FKZ/157/04	06/06	04.02.57	50.0/ 77.8	37.6/ 75.5	5.5	3.5	2.7	2.0	1.8	0	PX(13)
TUR/161/09	06/10	09.31.54	39.1/ 29.6	24.7/143.3	4.9	4.3	-	-	-	N	P (16)
FRS/165/13	06/14	13.48.56	56.2/123.6	51.6/ 40.9	5.6	5.6	-	201	239	N	P (11)
FRS/165/14	06/14	14.25.57	56.2/123.5	51.6/ 41.0	4.6	-	-	-	-	N	P (16)
KAM/166/14	06/15	14.04.08	52.8/16[illegible].8	63.8/ 19.7	5.1	4.7	-	69	72	55	P (11)
SIN/166/22	06/15	22.04.13	41.5/ 79.3	44.5/ 83.3	5.6	4.8	-	254	463	N	P (15)
SIN/166/23	06/15	23.17.34	41.6/ 79.2	44.4/ 83.3	4.9	4.1	-	22	28	N	P (12)
FKZ/170/04	06/19	04.03.58	50.0/ 77.7	37.6/ 75.6	5.5	3.3	2.9	1.1	1.2	0	PX(15)
SIN/170/17	06/19	17.23.03	41.5/ 79.3	44.5/ 83.3	5.2	5.2	-	205	307	N	P (15)
KUR/190/16	07/09	16.44.16	43.5/147.7	69.9/ 31.9	4.9	4.9	-	217	224	46	P (19)
KUR/191/03	07/10	03.05.00	43.6/147.7	69.8/ 31.9	4.8	4.4	-	97	74	36	P (16)
KUR/191/09	07/10	09.01.35	45.0/150.5	69.2/ 29.3	4.6	3.4	-	-	-	N	P (13)

TABLE A-1

LIST OF EVENTS USED FOR EVALUATION
(PAGE 2 OF 21)

EVENT NAME	DATE	ORIGIN TIME	LATITUDE N/ LONGITUDE E	DELTA/ AZIMUTH	MB	MS RAY	MS LOVE	AR	AL	Z	NOTES
WRS/191/17	07/10	16.55.55	64.2/ 55.2	20.3/ 61.3	5.3	-	-	-	-	0	PX(13)
SRS/200/20	07/19	20.41.20	45.1/ 38.6	19.5/114.4	3.8	3.1	-	-	-	N	L (18)
CHI/209/13	07/27	12.48.32	39.0/ 78.0	45.8/ 96.6	5.3	4.6	-	-	-	N	L (14)
PSA/210/19	07/29	19.40.15	42.5/ 33.2	22.7/132.6	3.9*	2.6	-	-	-	N	L (16)
SIB/212/01	07/31	01.11.30	61.5/163.2	55.8/ 15.5	3.5	3.4	-	-	-	N	L (17)
KUR/213/02	08/01	02.06.07	50.4/156.8	65.4/ 23.1	5.6	5.4	-	-	-	20	P (19)
SIN/219/15	08/07	15.21.53	36.1/ 77.7	48.0/ 89.3	4.8	4.3	-	125	263	N	P (15)
SIN/221/01	08/09	01.03.17	42.1/ 93.4	46.0/ 79.4	4.2	3.4	-	40	58	N	P (13)
CHI/229/09	08/17	09.36.16	28.9/103.7	66.4/ 72.7	4.9	4.5	-	59	75	N	P (11)
CHI/229/17	08/17	17.07.40	28.9/103.7	66.4/ 72.7	4.9	4.0	-	30	31	N	P (7)
CRS/236/16	08/24	16.33.23	52.2/ 91.4	42.3/ 63.9	5.2	5.7	-	904	834	N	P (15)
SIN/241/15	08/29	15.16.57	36.5/ 78.5	48.0/ 88.3	5.0	-	-	-	-	N	P (9)
CHI/249/21	09/06	21.46.46	43.8/123.6	62.1/ 48.9	3.8	3.5	-	77	128	N	P (15)
TRS/251/22	09/08	22.35.16	41.1/ 43.8	28.1/119.6	4.8	4.4	-	260	398	N	P (15)
CHI/258/07	09/15	07.10.47	33.0/101.0	61.7/ 72.4	4.2	3.10	-	-	-	N	N (12)
CHI/258/11	09/15	11.22.43	34.0/101.0	60.8/ 71.7	4.2	-	-	-	-	N	N (14)
TDZ/259/10	09/16	10.59.27	40.0/ 68.0	40.2/ 94.5	4.2	-	-	-	-	N	N (9)
CAU/262/05	09/19	06.44.49	43.0/ 47.1	29.0/113.0	4.4	-	-	-	-	N	L (11)
BLS/263/06	09/20	06.16.58	44.0/ 33.0	21.4/132.0	4.0	3.7	-	836	656	N	L (14)
BLS/263/08	09/20	08.02.51	43.2/ 32.9	22.0/133.2	4.2	-	-	-	-	N	L (14)
BLS/263/10	09/20	10.57.49	43.3/ 32.3	21.7/134.1	4.2	3.5	-	163	173	N	L (10)
FRS/266/21	09/23	21.08.03	53.4/120.3	52.8/ 44.9	4.2	3.2	-	-	-	15	L (12)
SIN/273/12	09/30	12.43.45	50.0/ 88.0	42.4/ 68.4	4.5	4.2	-	79	65	N	N (15)
TDZ/274/16	10/01	16.27.48	38.6/ 69.8	42.1/ 94.1	4.9	4.3	-	97	36	36	P (15)
EKZ/282/06	10/09	06.02.57	50.0/ 77.7	37.6/ 75.6	5.4	2.8	-	2.5	-	0	PX(13)

TABLE A-1

LIST OF EVENTS USED FOR EVALUATION
(PAGE 3 OF 21)

EVENT NAME	DATE	ORIGIN TIME	LATITUDE N/ LONGITUDE E	DELTA/ AZIMUTH	MB	MS RAY	MS LOVE	AR	AL	Z	NOTES
CAU/283/09	10/10	09.06.06	43.1/ 43.8	26.4/117.0	4.0	3.3	-	114	191	15	L (12)
CAU/288/17	10/15	17.08.06	41.4/ 48.6	29.9/113.1	4.9	3.6	-	45	42	N	P (15)
EKZ/294/06	10/21	06.02.57	50.0/ 77.6	37.6/ 75.6	5.6	3.1	3.1	2.7	2.2	0	PX(10)
KRG/301/13	10/28	13.30.57	41.9/ 72.4	40.9/ 88.7	5.5	5.2	-	227	298	N	P (15)
TIB/302/17	10/29	17.16.52	34.0/ 86.0	53.7/ 83.8	5.0	4.7	-	50	75	N	N (13)
EKZ/333/06	11/29	06.02.57	49.8/ 78.1	37.9/ 75.5	5.5	3.4	3.2	2.9	2.9	0	PX(9)
EKZ/349/07	12/15	07.52.59	50.0/ 77.9	37.7/ 75.4	4.9	-	-	-	-	0	PX(17)
WKZ/356/06	12/22	06.59.56	47.9/ 48.2	24.8/104.4	6.0	4.5	3.3	12	3.2	0	PX(17)
EKZ/364/06	12/30	06.20.58	49.7/ 78.1	38.0/ 75.6	5.9	3.9	3.6	3.9	2.2	0	PX(13)
SIB*001*15NL	01/01	15.04.19	59.7/153.8	56.1/ 21.5	4.1	-	-	-	-	N	L (12)
KUR*001*16NL	01/01	16.55.06	50.7/155.8	65.0/ 23.7	4.6	-	3.6	-	44	N	L (16)
KUR*001*18NL	01/01	18.13.54	49.4/156.5	66.3/ 23.7	4.0	3.6	-	-	-	N	L (14)
KUR*002*05NB	01/02	05.37.25	46.1/146.2	67.1/ 32.0	4.0	-	-	-	-	N	L (17)
GRE*002*09NA	01/02	09.17.53	37.9/ 20.7	22.8/160.5	4.2	2.5	2.6	40	46	N	P (14)
SIN*002*10NA	01/02	10.27.35	41.8/ 94.5	46.9/ 78.8	5.2	4.2	4.2	29	30	N	P (19)
KAM*003*06NL	01/03	06.36.38	51.6/159.4	64.8/ 21.0	4.8	3.9	3.0	56	55	N	P (13)
KAM*003*19NL	01/03	19.26.43	52.0/159.0	64.3/ 21.2	4.5	-	3.5	-	47	N	N (16)
FRS*003*23NL	01/03	23.40.37	58.8/130.8	51.6/ 35.0	3.4	-	-	-	-	N	L (15)
KAM*004*02NL	01/04	02.29.18	55.6/161.2	61.2/ 18.6	4.3	3.50	3.6	-	128	N	L (15)
TAI*004*05NC	01/04	05.08.48	22.4/122.0	80.2/ 61.1	4.8	3.9	4.1	365	461	N	P (17)
KAM*004*10NL	01/04	10.42.31	55.6/163.8	61.6/ 17.0	4.4	-	-	-	-	N	L (14)
TAI*004*12NA	01/04	12.15.17	22.4/122.2	80.3/ 60.9	4.6*	4.9	5.1	360	547	N	P (16)
KUR*005*02NL	01/05	02.16.10	43.8/147.2	69.5/ 32.2	4.5	3.4	3.2	32	29	N	P (12)
AUS*005*04NA	01/05	04.57.41	47.8/ 16.2	13.4/164.4	4.0	2.6	2.8	112	109	N	P (12)
TRZ*005*12NA	01/05	12.02.54	37.3/ 73.1	44.4/ 91.9	4.5	3.0	2.9	22	23	N	L (14)

TABLE A-1

LIST OF EVENTS USED FOR EVALUATION
(PAGE 4 OF 21)

EVENT NAME	DATE	ORIGIN TIME	LATITUDE N/ LONGITUDE E	DELTA/ AZIMUTH	MB	MS RAY	MS LOVE	AR	AL	Z	NOTES
KOM*005*14NL	01/05	14.26.48	56.6/169.4	61.3/ 13.3	4.0	-	-	-	-	N	L (14)
KAM*005*16NL	01/05	16.09.50	57.3/160.5	59.5/ 18.5	3.9	3.20	3.30	-	-	N	L (12)
KRG*006*06NC	01/06	06.30.36	40.7/ 72.4	41.8/ 89.8	4.7	3.4	3.0	23	13	N	P (13)
TAI*006*06NL	01/06	06.33.34	23.3/123.4	80.0/ 59.5	4.7	4.0	4.2	36	36	N	P (12)
IRA*006*09NL	01/06	09.41.33	30.3/ 50.5	40.1/121.3	5.2	3.6	3.6	15	16	N	P (14)
SWR*007*20NL	01/07	20.37.32	44.1/ 45.1	26.2/114.0	4.2	-	-	-	-	N	L (6)
KOM*009*03NL	01/09	03.23.06	54.4/164.4	62.9/ 17.0	3.6	-	-	-	-	N	L (17)
KAM*009*14NL	01/09	14.00.59	55.7/163.6	61.5/ 17.1	4.3	-	3.90	-	-	N	P (14)
KUR*009*14NL	01/09	14.47.46	45.1/148.4	68.6/ 30.8	3.8	-	-	-	-	N	L (15)
TAI*010*05NL	01/10	05.23.52	20.9/120.4	80.8/ 63.1	5.0	4.3	4.7	49	82	N	P (16)
KOM*011*08NL	01/11	08.54.34	54.7/168.2	63.1/ 14.5	3.9	-	-	-	-	N	L (15)
GRE*012*13NL	01/12	13.51.20	35.0/ 23.5	27.1/156.9	4.9	4.2	3.9	267	153	N	P (18)
KAM*012*20NL	01/12	20.20.15	55.6/163.9	61.6/ 16.9	4.8	4.2	4.3	111	127	N	P (17)
SIB*013*17NL	01/13	17.24.07	61.9/147.1	52.8/ 24.2	5.3	5.2	5.0	442	219	N	P (19)
SIB*014*03NA	01/14	03.20.20	67.5/171.5	50.9/ 9.4	3.9	3.2	3.1	187	186	N	P (15)
IRA*014*22NL	01/14	22.10.04	32.8/ 46.9	36.5/123.7	5.1	3.7	4.0	40	51	N	P (17)
KUR*015*00NA	01/15	00.58.33	49.6/155.0	65.8/ 24.6	3.9	-	-	-	-	N	L (20)
ERS*015*18NL	01/15	18.07.58	57.4/120.7	49.7/ 41.6	4.7	3.6	3.9	37	66	N	P (16)
KAM*016*04NL	01/16	04.38.16	55.6/162.5	61.4/ 17.8	3.8	-	-	-	-	N	L (17)
KAM*016*11NL	01/16	11.00.49	55.6/163.2	61.5/ 17.4	3.9	-	-	-	-	N	L (14)
CRE*017*05NL	01/17	05.54.20	34.5/ 26.5	28.2/152.0	4.1	2.8	2.9	72	72	N	L (16)
IRA*018*21NL	01/18	21.12.02	37.5/ 48.7	33.2/117.3	4.9	3.4	3.9	48	86	N	P (16)
DOD*020*02NL	01/20	02.15.07	36.6/ 27.1	26.3/149.6	4.8	4.0	3.7	171	103	N	P (18)
CAU*021*23NL	01/21	23.30.46	43.2/ 45.3	27.0/115.0	3.8	-	-	-	-	N	L (18)
KUR*022*01NL	01/22	01.41.24	50.0/152.0	64.8/ 26.5	4.2	3.00	-	-	-	N	N (16)

TABLE A-1

LIST OF EVENTS USED FOR EVALUATION
(PAGE 5 OF 21)

EVENT NAME	DATE	ORIGIN TIME	LATITUDE N/ LONGITUDE E	DELTA/ AZIMUTH	MB	MS RAY	MS LOVE	AR	AL	Z	NOTES
TUR*022*17NL	01/22	17.17.31	37.6/ 29.9	26.1/144.1	4.4	2.7	2.6	-	-	N	P (16)
KAM*025*10NL	01/25	10.02.40	53.9/160.9	62.8/ 19.3	4.6	-	-	-	-	N	P (16)
CRE*026*12NA	01/26	12.54.39	34.5/ 25.5	28.0/153.7	4.0	2.7	-	68	-	N	L (14)
KAM*027*20NL	01/27	20.37.28	55.7/162.3	61.3/ 17.9	3.8	-	-	-	-	N	L (14)
CHI*028*04NL	01/28	04.22.28	27.5/126.5	77.5/ 55.0	4.4	4.0	4.0	86	90	N	L (15)
IWP*029*10NL	01/28	10.26.54	26.6/ 66.3	50.3/107.0	4.1*	3.9	3.9	-	-	N	P (13)
KRG*028*20NL	01/28	20.29.19	43.0/ 78.0	42.8/ 82.9	4.4	2.9	3.4	23	39	N	N (17)
FRS*028*21NL	01/28	21.50.00	45.0/136.0	65.2/ 39.6	4.0	-	-	-	-	N	N (15)
KUR*028*23NL	01/28	23.42.51	49.3/157.3	66.6/ 23.1	3.8	-	3.20	-	-	N	L (18)
IRA*029*09NL	01/29	09.50.58	29.0/ 62.0	46.3/109.7	3.9	3.1	2.9	90	104	N	N (19)
CHI*030*03NL	01/30	03.56.41	40.9/120.2	63.3/ 53.0	3.9	4.2	4.2	350	338	N	L (17)
KAM*032*10NL	02/01	10.16.09	55.8/162.8	61.3/ 17.6	4.1	-	-	-	-	N	L (14)
SIR*032*17NL	02/01	17.06.25	59.3/155.7	56.8/ 20.6	3.6	-	-	-	-	N	L (12)
KAM*033*04NL	02/02	04.26.59	55.7/162.0	61.2/ 18.1	3.7	-	-	-	-	N	L (18)
KUR*033*09NL	02/02	09.58.51	46.8/146.4	66.5/ 31.5	3.6	-	-	-	-	N	L (14)
KUR*033*17NL	02/02	17.56.39	50.7/160.1	65.8/ 20.8	3.6	-	-	-	-	N	L (18)
GRF*033*21NL	02/02	21.19.49	38.9/ 21.2	22.9/159.0	4.6	3.3	3.6	102	154	N	P (19)
CHI*034*07NL	02/03	07.22.49	23.4/102.4	70.4/ 76.8	4.5	4.1	4.5	118	200	N	P (17)
ITA*035*02NL	02/04	02.42.19	43.8/ 13.3	17.1/174.1	4.5*	3.7	4.3	300	925	N	P (15)
BKL*035*03NL	02/04	03.34.56	51.4/118.0	53.6/ 47.8	4.2	3.4	3.1	58	45	N	L (15)
ITA*035*09NL	02/04	09.18.32	43.9/ 13.2	17.0/174.3	4.4	3.4	3.9	159	466	N	P (14)
ITA*035*17NL	02/04	17.19.52	43.8/ 13.3	17.1/174.1	4.1*	3.3	3.8	401	834	N	P (17)
ITA*035*19NL	02/04	19.02.56	43.8/ 13.3	17.1/174.1	4.1*	2.6	3.2	80	198	N	P (15)
ITA*036*03NL	02/05	03.49.45	43.2/ 13.7	17.7/173.2	3.7*	2.3	2.8	107	280	N	P (18)
ITA*036*05NL	02/05	05.05.51	43.7/ 13.5	17.2/173.6	4.0*	2.8	3.3	175	345	N	P (19)

TABLE A-1

LIST OF EVENTS USED FOR EVALUATION
(PAGE 6 OF 21)

EVENT NAME	DATE	ORIGIN TIME	LATITUDE N/ LONGITUDE E	DELTA/ AZIMUTH	MB	MS RAY	MS LOVE	AR	AL	Z	NOTES
ITA*036*07NL	02/05	07.08.13	43.9/ 13.3	17.0/174.0	4.3*	3.2	3.6	137	275	N	P (18)
ITA*036*15NL	02/05	15.14.48	43.7/ 13.4	17.2/173.8	4.2*	3.4	3.9	379	757	N	P (18)
ITA*037*01NL	02/06	01.34.22	44.0/ 13.2	16.9/174.3	4.4*	3.1	3.7	101	273	N	P (19)
TIP*037*04NL	02/06	04.29.05	29.0/ 90.0	59.3/ 84.7	4.1	-	-	-	-	N	N (19)
ITA*037*21NL	02/06	21.44.29	43.8/ 13.2	17.1/174.3	3.8*	-	2.6	-	116	N	P (20)
ITA*039*12NL	02/08	12.19.15	43.8/ 13.3	17.1/174.1	4.3*	2.5	2.9	35	71	N	P (16)
FKZ*041*05NL	02/10	05.02.57	50.0/ 78.9	38.2/ 74.7	5.5	2.7	-	1.2	-	0	PX(19)
IRA*041*09NL	02/10	09.04.09	29.6/ 50.9	40.9/121.4	3.9	3.1	3.4	153	252	N	P (19)
IRA*041*16NL	02/10	16.40.16	29.5/ 50.9	41.0/121.4	4.1	3.2	3.4	120	199	N	P (19)
SIN*042*05NL	02/11	05.55.46	39.9/ 77.4	44.8/ 86.2	4.9	4.2	4.3	56	67	N	P (18)
TIP*042*12NA	02/11	12.20.43	29.0/ 87.0	58.3/ 86.4	4.3	-	-	-	-	N	N (16)
KAM*042*21NA	02/11	21.36.17	56.1/162.9	61.0/ 17.4	4.6	3.9	4.2	124	156	N	P (18)
KUR*044*05NA	02/13	05.24.57	43.5/147.0	69.7/ 32.4	3.8	-	-	-	-	N	L (21)
GRE*044*13NL	02/13	13.07.11	37.1/ 24.0	25.1/154.9	4.5	3.2	3.8	89	192	N	P (21)
KOM*044*22NA	02/13	22.36.54	55.2/165.5	62.2/ 16.1	3.9	3.8C	3.8C	-	-	N	L (21)
KUR*046*16NL	02/15	16.45.22	45.0/153.0	69.8/ 27.6	4.1	3.0	2.7C	42	-	N	L (18)
GRE*047*00NL	02/16	00.42.24	36.9/ 24.2	25.4/154.6	4.5	2.9	3.4	39	88	N	P (20)
SIN*047*23NE	02/16	23.19.20	41.7/ 80.7	45.1/ 82.0	4.8	4.0	3.5	41	22	N	P (16)
KUR*049*18NA	02/18	18.02.34	43.6/147.8	69.6/ 31.8	4.7	3.8	3.8	39	52	N	P (18)
SIN*051*10NL	02/20	10.22.46	38.5/ 90.5	52.2/ 76.8	3.9	3.2	2.9	67	53	N	I (19)
KAM*051*20NL	02/20	20.06.11	50.8/141.5	61.6/ 33.1	4.1	3.2	-	61	-	N	I (19)
KAM*052*22NL	02/21	22.00.59	54.4/161.3	62.4/ 18.9	4.3	3.7	-	56	-	N	I (21)
YUG*052*23NA	02/21	23.02.55	41.0/ 22.3	21.0/155.4	4.0	-	-	-	-	N	I (18)
MON*053*01NC	02/22	01.53.36	49.0/115.0	54.5/ 51.4	4.1	-	-	-	-	N	I (14)
KAM*053*03NC	02/22	03.38.29	56.0/156.0	60.0/ 21.7	3.4	-	-	-	-	N	J (17)

TABLE A-1

LIST OF EVENTS USED FOR EVALUATION
(PAGE 7 OF 21)

EVENT NAME	DATE	ORIGIN TIME	LATITUDE N/ LONGITUDE E	DELTA/ AZIMUTH	MB	MS RAY	MS LOVE	AR	AL	Z	NOTES
HNK*053*08NA	02/22	08.14.26	36.6/ 68.6	43.1/ 97.1	4.0	3.2	3.1	112	68	N	J (17)
KUR*054*03NA	02/23	03.07.04	43.7/148.4	69.9/ 31.3	4.8	4.0	4.3	62	87	N	I (19)
KUR*054*27NB	02/23	03.21.31	44.2/148.4	69.4/ 31.1	4.7	3.9	4.2	54	80	N	I (18)
KUR*054*37NB	02/23	03.42.41	43.9/148.3	69.7/ 31.3	4.9	4.0	4.2	40	56	N	I (18)
ARC*054*09NL	02/23	09.46.50	86.0/139.0	31.8/ 6.0	3.7	-	-	-	-	N	J (17)
KAM*054*19NL	02/23	19.37.29	55.0/163.0	62.1/ 17.7	3.7	-	-	-	-	N	J (19)
KUR*055*10NA	02/24	10.19.37	48.8/155.7	66.7/ 24.4	5.0	4.9	4.5	297	132	N	P (13)
KUR*055*18NL	02/24	18.17.34	49.0/158.0	67.0/ 22.8	3.5	-	-	-	-	N	J (19)
KUR*056*19NA	02/25	19.59.29	46.0/147.0	67.4/ 31.4	3.8	-	-	-	-	N	J (16)
WRS*056*22NC	02/25	22.34.49	50.0/ 38.0	18.6/113.3	3.7	-	-	-	-	N	J (19)
KUR*056*22NL	02/25	22.43.07	49.2/156.0	66.4/ 24.1	4.0	3.3	3.10	102	-	N	I (19)
KUR*057*02NL	02/26	02.12.57	49.2/156.2	66.5/ 23.9	4.9	4.8	4.5	207	153	N	I (18)
KUR*057*05NL	02/26	05.58.22	46.8/152.6	68.0/ 27.2	4.9	3.5	3.5	23	16	N	I (19)
KAM*057*09NL	02/26	09.04.32	55.0/162.0	61.9/ 18.3	3.3	-	-	-	-	N	J (20)
SIP*057*15NL	02/26	15.06.42	53.3/138.7	58.6/ 33.6	3.8	-	-	-	-	N	I (18)
OKH*057*18NA	02/26	18.32.26	51.0/149.0	63.2/ 28.1	4.0	-	-	-	-	N	J (17)
YUN*057*18NL	02/26	18.56.13	27.1/100.9	66.6/ 76.0	4.7	3.9	4.0	36	39	N	P (17)
NRS*058*08NL	02/27	08.42.53	88.0/ -74.	29.0/ -4.1	3.3	-	-	-	-	N	I (10)
NRS*058*32NL	02/27	08.48.08	89.0/ 15.0	28.2/ 0.1	3.3	-	-	-	-	N	J (10)
NRS*058*10NL	02/27	10.03.03	87.0/ 53.5	27.0/ 4.5	4.9	3.9	3.6	151	126	N	I (19)
NRS*058*11NL	02/27	11.03.19	90.0/ -95.	29.2/ 0.0	3.5	-	-	-	-	N	I (19)
NRS*058*17NL	02/27	17.50.25	86.2/ 77.2	27.8/ 7.5	4.4	2.9	2.7	40	47	N	I (18)
BAI*058*22NL	02/27	22.15.03	55.0/ 93.2	41.2/ 59.7	4.5	3.1	3.0	25	23	N	I (20)
KUR*059*01NL	02/28	01.04.22	46.0/148.0	67.7/ 30.7	4.2	-	-	-	-	N	I (20)
PAK*059*05NL	02/28	05.18.56	36.7/ 71.4	44.4/ 34.4	4.2	2.8C	-	-	-	N	I (19)

TABLE A-1

LIST OF EVENTS USED FOR EVALUATION
(PAGE 8 OF 21)

EVENT NAME	DATE	ORIGIN TIME	LATITUDE N/ LONGITUDE E	DELTA/ AZIMUTH	MB	MS RAY	MS LOVE	AR	AL	Z	NOTES
KAM*059*11NL	02/28	11.35.31	56.0/163.0	61.1/ 17.4	4.1	-	-	-	-	N	I (19)
AFG*059*18NL	02/28	18.12.35	36.0/ 68.7	43.7/ 97.5	4.4	3.9	3.4	151	64	N	I (12)
KAM*059*20NL	02/28	20.04.00	56.1/164.2	61.2/ 16.6	3.6	-	-	-	-	N	I (17)
IRQ*060*08NL	02/29	08.02.51	32.8/ 46.6	36.3/124.1	4.0	2.7C	3.2	-	110	N	I (19)
NRS*060*08NL	02/29	08.07.21	89.0/ -51.	28.7/ -1.8	3.4	-	-	-	-	N	J (18)
IRA*062*14NL	03/02	14.10.13	31.6/ 42.1	35.7/130.8	4.0	-	-	-	-	N	I (13)
ALM*062*19NL	03/02	19.57.42	43.0/ 76.0	41.8/ 84.5	3.5	-	-	-	-	N	J (20)
KAM*063*00NL	03/03	00.39.23	53.0/159.2	63.4/ 20.7	4.1	-	-	-	-	N	I (16)
SIB*063*05NL	03/03	05.26.53	77.9/116.7	34.4/ 21.1	3.8	-	-	-	-	N	I (21)
KOM*063*08NL	03/03	08.13.55	55.8/163.9	61.4/ 16.9	4.1	-	-	-	-	N	I (18)
YUG*063*21NL	03/03	21.26.51	44.7/ 18.4	16.7/161.2	4.4*	3.4	3.7	-	-	N	I (20)
KUR*063*23NL	03/03	23.10.41	50.2/155.7	65.4/ 23.9	4.5	3.8	3.5	87	48	N	I (20)
SIN*064*04NL	03/04	04.00.09	40.2/ 79.0	45.4/ 84.7	4.5	3.9	3.6	87	53	N	I (20)
KAM*066*06NL	03/06	06.05.08	53.5/160.9	63.2/ 19.5	3.9	-	-	-	-	N	I (20)
KUR*066*09NL	03/06	09.59.09	45.0/150.0	69.1/ 29.7	3.7	-	-	-	-	N	J (19)
OKH*066*19NL	03/06	19.13.25	56.0/140.0	56.5/ 31.4	4.2	-	-	-	-	N	J (20)
CHI*066*23NL	03/06	23.17.53	40.0/103.0	56.8/ 66.2	4.5	-	-	-	-	N	J (20)
YUG*067*05NL	03/07	05.21.21	43.0/ 21.0	18.9/156.6	2.7	-	-	-	-	N	I (20)
OKH*068*02NL	03/08	02.38.11	51.2/151.9	63.7/ 26.1	4.2	-	-	-	-	N	I (19)
IRA*068*21NL	03/08	21.49.11	27.6/ 56.7	45.1/116.3	4.6*	3.7	3.5	66	43	N	I (19)
BUL*068*22NL	03/08	22.04.02	40.8/ 22.8	21.3/154.6	3.5	2.9	3.0	653	578	N	I (19)
EKZ*070*04NL	03/10	04.56.57	49.8/ 78.2	38.0/ 75.4	5.5	3.3	3.3	2.4	1.8	O	IX(17)
KUR*070*06NL	03/10	06.50.18	45.1/149.5	68.9/ 30.0	3.7	2.8C	3.1C	-	-	N	I (19)
ARC*071*06NL	03/11	06.4 .07	82. /143.3	35.0/ 10.3	3.6	-	-	-	-	N	I (21)
KAS*071*13NL	03/11	13.31.39	35.0/ 76.0	48.0/ 91.7	4.1	-	-	-	-	N	J (20)

TABLE A-1

LIST OF EVENTS USED FOR EVALUATION
(PAGE 9 OF 21)

EVENT NAME	DATE	ORIGIN TIME	LATITUDE N/ LONGITUDE E	DELTA/ AZIMUTH	MB	MS RAY	MS LOVE	AR	AL	Z	NOTES
KUR*073*02NL	03/13	02.11.05	49.0/158.0	67.0/ 22.8	3.8	-	-	-	-	N	I (20)
AFG*073*05NL	03/13	05.49.13	37.0/ 70.0	43.5/ 95.4	4.0	-	-	-	-	N	I (20)
TIP*073*18NC	03/13	18.27.07	34.0/ 83.0	52.2/ 86.4	4.1	-	-	-	-	N	J (17)
IDA*074*02NT	03/14	02.43.37	44.0/-116.	66.7/-38.8	3.7	-	-	-	-	N	J (18)
TIB*075*06NL	03/15	06.00.33	30.4/ 84.5	55.9/ 87.6	5.3	3.9	3.9	17	19	N	I (20)
ARZ*077*00NL	03/17	00.29.01	32.3/-116.	77.2/-44.2	4.1	-	-	-	-	N	I (17)
KUR*077*07NL	03/17	07.49.02	49.0/156.2	66.7/ 24.0	5.2	4.5	4.1	61	44	N	I (19)
TAD*077*09NL	03/17	09.17.11	40.1/ 69.7	40.9/ 92.8	5.2	4.9	4.5	166	149	N	I (18)
IRA*077*17NL	03/17	17.11.28	28.0/ 54.0	43.6/119.0	3.9	-	-	-	-	N	J (19)
KAS*077*23NL	03/17	23.33.37	32.0/ 75.0	50.0/ 94.9	3.5	-	-	-	-	N	J (18)
EKZ*078*07NL	03/18	07.11.55	47.0/ 81.0	41.3/ 76.5	3.6	2.9	-	114	-	N	J (20)
KAM*078*13NL	03/18	13.52.14	57.0/163.0	60.1/ 17.1	3.6	-	-	-	-	N	J (21)
KAM*078*18NL	03/18	18.29.37	50.6/156.7	65.2/ 23.1	4.7	3.5	3.5	33	27	N	I (19)
OKH*078*19NL	03/18	19.17.25	54.0/150.0	60.7/ 26.2	3.7	-	-	-	-	N	J (19)
KIR*078*19NL	03/18	19.54.18	41.0/ 72.0	41.4/ 89.9	3.2	-	-	-	-	N	J (19)
CAU*079*03NL	03/19	03.34.31	42.7/ 38.1	24.4/125.6	3.9	2.7	3.0	75	167	N	I (19)
SIN*080*10NL	03/20	10.54.35	38.0/ 73.0	44.2/ 91.8	3.9	-	-	-	-	N	J (19)
KUR*080*14NL	03/20	14.08.12	47.0/154.0	68.1/ 26.2	4.0	-	-	-	-	N	J (20)
SIN*080*21NL	03/20	21.47.55	40.0/ 80.0	46.0/ 84.0	3.4	-	-	-	-	N	J (17)
EKZ*088*04NL	03/28	04.21.57	49.7/ 78.2	38.0/ 75.6	5.2	2.9	2.8	3.6	3.1	O	PY(18)
KUR*153*00NL	06/01	00.18.13	48.0/154.0	67.2/ 25.8	3.9	3.3	3.3	99	110	N	L (15)
CKZ*153*01NL	06/01	01.23.26	52.0/ 70.0	32.6/ 78.5	3.6	-	-	-	-	N	L (16)
MON*153*11NL	06/01	11.22.15	44.0/103.0	53.6/ 63.3	3.7	2.9	3.3	-	126	N	N (14)
KOM*153*21NA	06/01	21.43.49	55.0/164.0	62.2/ 17.0	3.8	3.2	3.1	117	80	N	L (12)
KZH*154*05NL	06/02	05.11.13	43.0/ 81.0	44.2/ 80.5	3.5	-	-	-	-	N	N (13)

TABLE A-1

LIST OF EVENTS USED FOR EVALUATION
(PAGE 10 OF 21)

EVENT NAME	DATE	ORIGIN TIME	LATITUDE N/ LONGITUDE E	DELTA/ AZIMUTH	MB	MS RAY	MS LOVE	AR	AL	Z	NOTES
SIN*154*06NL	06/02	06.30.49	42.0/ 81.0	45.0/ 81.4	3.9	3.0	3.6	95	150	N	N (17)
CHI*154*16NA	06/02	16.49.22	36.0/ 92.0	55.0/ 77.5	3.7	3.5	3.9	356	483	N	N (11)
IND*154*20NA	06/02	20.32.55	28.4/ 95.9	63.1/ 79.3	4.3	3.20	3.4	-	45	N	P (9)
RYU*155*02NA	06/03	02.16.51	23.5/125.5	80.7/ 57.7	5.0*	4.7	4.7	76	53	N	P (14)
IRA*155*08NA	06/03	08.21.30	29.0/ 53.0	42.3/119.4	4.2	2.6	3.1	24	59	N	N (13)
IRA*156*03NA	06/04	03.37.49	30.0/ 54.0	41.9/117.5	4.2	2.60	2.6	-	-	N	N (17)
KAM*156*07NA	06/04	07.52.38	53.0/158.0	63.2/ 21.5	4.0	3.0	-	44	-	N	L (17)
TUR*156*16NA	06/04	16.29.34	39.4/ 26.2	23.4/149.1	4.1	2.5	2.7	-	-	17	P (16)
CHI*156*23NA	06/04	23.22.18	33.0/ 97.0	59.8/ 75.5	3.5	3.10	3.3	-	252	N	N (13)
KAM*157*04NA	06/05	04.12.54	56.2/163.1	60.9/ 17.3	4.3	3.1	3.3	38	46	N	P (11)
GRE*157*10NA	06/05	10.44.59	37.8/ 21.4	24.0/159.2	4.2	3.6	3.6	406	331	69	P (12)
IRA*157*11NL	06/05	11.17.57	34.0/ 46.0	35.0/123.8	3.9	2.8	3.4	105	163	N	N (14)
PAK*157*11NL	06/05	11.52.53	29.8/ 70.3	49.5/100.9	4.8	3.5	3.6	20	25	27	P (14)
LOM*157*19NL	06/05	19.00.12	86.5/ 38.9	26.1/ 3.7	4.4	3.0	2.8	62	50	N	P (15)
KUR*158*06NL	06/06	06.32.10	49.0/155.0	66.4/ 24.8	3.6	-	-	-	-	N	L (17)
TAI*160*10NA	06/08	10.17.44	21.0/120.2	80.6/ 63.2	4.9	4.5	4.6	66	62	N	P (13)
TRS*160*12NA	06/08	12.46.15	41.0/ 44.0	28.2/119.4	4.1	2.5	3.0	-	-	N	L (12)
BUR*160*16NA	06/08	16.08.06	19.0/ 94.0	70.2/ 86.4	4.3	3.7	3.9	70	111	N	N (12)
TIB*160*23NA	06/08	23.10.12	29.5/ 92.3	60.4/ 81.6	4.7	3.9	4.0	46	49	64	P (12)
GRE*161*07NA	06/09	07.42.20	34.8/ 26.5	27.9/151.8	4.9	4.0	4.1	233	199	N	P (9)
PAK*162*11NL	06/10	11.29.11	28.2/ 66.5	49.1/105.7	4.5	3.8	3.8	104	-	N	P (15)
KUR*162*19NL	06/10	19.21.53	43.0/150.0	71.0/ 30.4	3.7	2.8	-	-	-	N	L (17)
IRA*162*19NL	06/10	19.31.42	32.9/ 46.3	36.1/124.4	4.0	3.0	3.5	109	173	N	P (18)
KAM*163*14NL	06/11	14.14.01	53.0/160.0	63.5/ 20.2	3.3	2.7	-	163	-	N	L (15)
KUR*163*23NL	06/11	23.23.04	48.0/152.0	66.7/ 27.2	4.0	-	-	-	-	N	L (19)

TABLE A-1

LIST OF EVENTS USED FOR EVALUATION
(PAGE 11 OF 21)

EVENT NAME	DATE	ORIGIN TIME	LATITUDE N/ LONGITUDE E	DELTA/ AZIMUTH	MB	MS RAY	MS LOVE	AR	AL	Z	NOTES
KUR*163*23N2	06/11	23.33.44	47.0/152.0	67.7/ 27.6	4.3	-	-	-	-	N	L (19)
KUR*164*00NL	06/12	00.19.16	44.0/148.0	69.5/ 31.5	3.7	-	-	-	-	N	L (19)
IRA*164*13NL	06/12	13.34.01	33.1/ 46.3	35.9/124.2	5.4	4.7	5.3	199	287	N	P (17)
KAM*164*22NA	06/12	22.37.38	53.0/162.0	63.8/ 18.9	3.7	-	-	-	-	N	L (16)
IRA*165*00NL	06/13	00.55.37	33.1/ 46.3	35.9/124.2	5.1	4.1	4.6	137	181	N	P (12)
KAM*165*04NL	06/13	04.53.30	55.0/162.0	61.9/ 18.3	3.8	-	-	-	-	N	L (12)
CAU*166*00NL	06/14	00.49.54	40.1/ 51.9	32.5/110.9	4.7	3.7	3.2	74	48	47	P (15)
IRA*166*04NL	06/14	04.34.28	33.0/ 46.1	36.0/124.6	5.3	3.9	4.4	46	55	N	P (17)
KOM*166*10NL	06/14	10.27.50	57.0/164.0	60.3/ 16.5	3.6	-	-	-	-	N	L (11)
IRA*166*12N1	06/14	12.35.05	27.0/ 56.0	45.3/117.5	3.6	-	-	-	-	N	N (12)
ITA*166*18NL	06/14	18.55.53	43.7/ 13.4	17.2/173.8	4.5*	4.0	4.3	939	953	14	P (15)
ITA*166*21NL	06/14	21.01.00	43.7/ 13.5	17.2/173.6	4.3*	2.8	3.3	98	164	6	P (13)
GRE*167*00NL	06/15	00.33.24	38.3/ 22.2	23.6/157.4	4.9	4.2	4.3	462	337	76	P (16)
KAM*168*09NL	06/16	09.54.41	56.0/161.0	60.8/ 18.6	4.1	-	-	-	-	N	L (11)
KAM*168*22NB	06/16	22.12.12	53.0/157.0	63.0/ 22.1	3.6	-	-	-	-	N	L (15)
IRA*168*23NL	06/16	23.22.27	34.0/ 46.0	35.0/123.8	3.7	3.0	3.2	144	166	N	N (14)
AUS*169*09NL	06/17	09.02.48	48.3/ 14.5	12.7/169.0	4.3*	2.9	2.6	95	42	N	P (11)
KUR*169*19NL	06/17	19.18.21	44.2/149.1	69.6/ 30.6	4.6	3.4	3.5	24	32	64	P (17)
TIB*170*04NL	06/18	04.30.47	33.0/ 83.0	53.0/ 97.1	4.3	3.8	3.9	113	133	N	N (16)
KUR*170*09NL	06/18	09.10.54	48.0/154.0	67.2/ 25.8	3.9	-	-	-	-	N	L (15)
SIN*170*09NA	06/18	09.18.49	40.0/ 73.0	42.6/ 90.0	4.3	-	-	-	-	N	L (14)
TUR*170*22NA	06/18	22.32.52	39.0/ 31.0	25.2/141.1	4.4	2.6	3.0	27	50	N	L (6)
KUR*171*18NA	06/19	18.07.53	43.8/151.5	70.6/ 29.1	4.5	3.7	3.5	55	39	N	P (14)
KUR*171*22NL	06/19	22.41.42	48.0/157.0	67.8/ 23.8	4.1	2.9	-	32	-	N	L (18)
ERS*172*09NL	06/20	09.18.09	52.0/131.0	57.5/ 39.2	3.7	2.7	2.9	-	71	N	L (13)

TABLE A-1

LIST OF EVENTS USED FOR EVALUATION
(PAGE 12 OF 21)

EVENT NAME	DATE	ORIGIN TIME	LATITUDE N/ LONGITUDE E	DELTA/ AZIMUTH	MB	MS RAY	MS LOVE	AR	AL	Z	NOTES
KAS*172*15NA	06/20	15.34.37	32.0/ 75.0	50.0/ 94.9	3.6	-	-	-	-	N	N (10)
TUR*173*05NL	06/21	05.06.17	40.2/ 30.0	23.8/141.6	4.1	3.3	3.1	165	103	N	P (15)
KAM*173*10NL	06/21	10.42.45	54.0/161.0	62.7/ 19.2	4.3	2.7	-	-	-	N	L (9)
TUR*175*04NA	06/23	04.25.27	41.0/ 30.0	23.0/140.9	3.7	2.8	3.1	232	256	N	L (18)
GRE*175*07NA	06/23	07.18.14	37.0/ 21.0	24.7/160.4	3.4	2.4	2.6	218	224	N	N (18)
IRA*175*08NL	06/23	08.39.36	32.9/ 46.2	36.1/124.5	4.6	3.2	3.8	46	75	40	P (17)
YUG*177*04NL	06/25	04.59.19	44.0/ 15.8	17.1/167.9	3.7*	2.5	2.3	130	94	N	P (18)
HNK*177*07NL	06/25	07.55.45	36.3/ 69.6	43.9/ 96.4	4.7	4.4	4.2	387	165	46	P (18)
KAM*177*17NL	06/25	17.35.50	54.0/160.0	62.6/ 19.9	4.1	3.3	3.6	79	139	N	L (19)
TAI*178*08NL	06/26	08.09.25	21.1/120.3	80.6/ 63.1	5.0	4.8	5.1	130	178	N	P (19)
KAM*178*17NL	06/26	17.32.32	56.0/158.0	60.3/ 20.5	3.6	-	-	-	-	N	L (18)
HNK*178*20NL	06/26	20.55.03	36.0/ 69.0	43.8/ 97.2	3.7	2.9	2.8	125	-	N	N (19)
PAK*179*06NL	06/27	06.39.44	29.7/ 70.3	49.6/100.9	5.5	4.9	4.6	74	57	N	P (11)
BUR*179*09NL	06/27	09.05.53	26.2/ 96.6	65.3/ 80.1	4.4	3.9	4.2	84	156	23	P (14)
PAK*179*10NL	06/27	10.48.56	29.7/ 70.3	49.6/100.9	5.2*	4.4	3.9	49	31	8	P (18)
WRS*179*12NL	06/27	12.20.36	51.0/ 47.0	22.1/100.0	3.5	-	-	-	-	N	L (17)
HNK*179*15NL	06/27	15.59.35	36.3/ 69.5	43.8/ 96.5	5.1	4.4	3.8	133	44	53	P (20)
YUG*180*01NA	06/28	01.43.56	43.0/ 20.5	18.8/157.7	4.6*	2.6	3.1	22	46	N	P (17)
CHI*180*03NA	06/28	03.09.59	33.0/ 91.0	56.9/ 80.4	3.6	3.0	3.3	119	221	N	N (15)
KOM*180*04AL	06/28	04.48.22	56.0/165.0	61.4/ 16.1	4.2	2.8	-	22	-	N	L (10)
KOM*180*06NL	06/28	06.00.22	55.0/164.0	62.2/ 17.0	3.4	-	-	-	-	N	L (15)
CYP*180*08NA	06/28	08.16.55	35.0/ 32.0	29.2/142.7	4.3	-	-	-	-	N	N (14)
UAR*180*09NA	06/28	09.49.35	27.6/ 33.8	36.7/144.7	5.6	4.6	4.8	140	185	15	P (17)
KAM*180*14NA	06/28	14.58.49	53.0/161.0	63.7/ 19.5	3.9	2.8	-	-	-	N	L (15)
KAZ*181*00NL	06/29	00.41.02	54.0/ 69.0	30.9/ 76.2	3.7	2.4	-	64	-	N	L (15)

TABLE A-1

LIST OF EVENTS USED FOR EVALUATION
(PAGE 13 OF 21)

EVENT NAME	DATE	ORIGIN TIME	LATITUDE N/ LONGITUDE E	DELTA/ AZIMUTH	MB	MS RAY	MS LOVE	AP	AL	Z	NOTES
AFG*181*03NL	06/29	03.32.11	38.9/ 71.4	42.7/ 92.4	4.6*	3.9	3.8	71	74	53	P (17)
TAI*182*18NL	06/30	18.57.43	24.3/121.1	78.1/ 60.9	4.9	4.8	5.4	135	385	N	P (19)
IRA*182*20NL	06/30	20.31.33	30.0/ 53.0	41.4/118.7	4.0	2.8	2.7	55	43	N	N (18)
KOM*183*02NL	07/01	02.10.18	54.0/166.0	63.5/ 16.1	3.4	-	-	-	-	N	L (17)
IRA*184*12NL	07/02	12.56.07	30.1/ 50.8	40.4/121.1	5.4	4.8	5.3	-	558	31	P (19)
IRA*184*14NL	07/02	14.05.06	30.0/ 50.8	40.5/121.2	4.6	3.3	3.3	46	43	31	P (20)
IRA*185*02NL	07/03	02.10.00	30.1/ 50.8	40.4/121.1	5.0	4.0	3.8	63	-	38	P (7)
IRA*185*12NL	07/03	12.31.05	30.0/ 53.0	41.4/118.7	4.0	2.9	-	41	-	N	N (13)
IRA*185*21NL	07/03	21.38.22	30.0/ 51.0	40.6/121.0	5.1	3.8	4.2	59	96	43	P (19)
TUR*186*06NL	07/04	06.17.25	41.0/ 33.0	24.0/135.7	3.4	2.8	2.5	385	254	N	L (17)
KAM*186*13NL	07/04	13.52.19	55.0/163.0	62.1/ 17.7	4.4	3.2	-	-	-	N	L (14)
KUR*186*21NL	07/04	21.47.57	49.0/151.0	65.6/ 27.5	3.6	2.7	-	-	-	N	L (13)
SIN*187*01NL	07/05	01.09.53	44.6/ 81.1	43.1/ 78.9	4.6	3.9	4.5	91	155	N	P (19)
SIN*187*04NL	07/05	04.09.49	43.6/ 87.9	47.0/ 74.6	4.3	3.1	3.0	29	25	N	P (14)
IRA*187*16NL	07/05	16.29.27	31.0/ 52.0	40.1/119.0	4.0	3.4	3.3	145	176	N	N (16)
IRA*187*21NL	07/05	21.41.08	30.0/ 54.0	41.9/117.5	4.1	2.8	2.8	-	38	N	N (20)
KAZ*188*01NA	07/06	01.02.58	49.7/ 78.0	37.9/ 75.7	4.4	-	-	-	-	0	PX(18)
IRA*188*05NL	07/06	05.41.43	27.0/ 55.0	44.9/118.6	3.1	2.8	-	260	-	N	N (15)
KAM*189*05NL	07/07	05.13.06	56.0/163.0	61.1/ 17.4	3.7	2.7	3.0	78	-	N	L (17)
CHI*189*23NL	07/07	23.43.41	32.0/102.0	63.0/ 72.2	3.7	3.7	3.7	-	311	N	N (17)
GRE*190*05NL	07/08	05.46.14	41.6/ 23.6	20.7/152.3	4.7	2.7	2.7	22	16	28	P (16)
KUR*190*21NL	07/08	21.07.27	48.0/151.0	66.5/ 27.9	4.2	3.1	3.1	34	36	N	L (20)
MED*191*13NL	07/09	13.21.22	36.0/ 19.0	25.4/164.5	4.0	2.5	3.0	-	111	N	L (18)
SIN*192*19NA	07/10	19.03.33	43.4/ 99.6	47.5/ 74.3	4.7	3.7	3.1	48	21	N	P (18)
AFG*193*04NL	07/11	04.20.41	37.0/ 72.0	44.5/ 93.6	4.2	-	-	-	-	N	L (14)

TABLE A-1

LIST OF EVENTS USED FOR EVALUATION
(PAGE 14 OF 21)

EVENT NAME	DATE	ORIGIN TIME	LATITUDE N/ LONGITUDE E	DELTA/ AZIMUTH	MB	MS RAY	MS LOVE	AR	AL	Z	NOTES
KUR*193*06NL	07/11	06.58.21	48.4/154.5	66.9/ 25.4	5.2	4.0	-	44	-	62	P (18)
KAM*193*08NA	07/11	09.53.49	55.0/163.0	62.1/ 17.7	3.6	-	3.00	-	-	N	L (14)
IRA*193*15NL	07/11	15.33.48	32.0/ 60.0	42.8/109.5	3.7	2.9	2.9	-	136	N	N (17)
IRA*193*22NL	07/11	22.49.02	36.1/ 45.7	33.1/122.4	4.7	3.8	3.5	111	-	N	P (18)
KUR*194*00NL	07/12	00.14.27	49.3/155.4	66.2/ 24.4	5.2	4.2	3.8	48	18	N	P (20)
PAK*194*01NL	07/12	01.21.18	33.0/ 73.0	48.2/ 95.9	3.5	-	-	-	-	N	N (18)
KUR*194*20NL	07/12	20.14.51	49.0/154.0	66.2/ 25.5	3.7	-	-	-	-	N	L (17)
TIB*195*05NL	07/13	05.27.44	31.0/ 89.0	57.6/ 83.4	3.9	-	3.7	-	122	N	N (17)
KUR*195*15NL	07/13	15.05.44	44.0/150.0	70.0/ 30.1	4.2	3.5	3.3	72	47	N	N (18)
PAK*195*18NL	07/13	18.50.53	28.0/ 63.0	47.6/109.4	3.7	3.3	-	165	-	N	N (15)
TAI*195*23NL	07/13	23.02.25	22.0/123.0	81.0/ 60.4	3.8	3.7	4.0	120	254	N	N (17)
TUR*196*04NL	07/14	04.38.45	36.0/ 31.0	27.9/143.6	3.9	-	-	-	-	N	N (20)
IRA*196*13NL	07/14	13.04.12	30.1/ 50.8	40.4/121.1	4.4	2.8	3.4	38	77	34	P (17)
IRA*196*13N2	07/14	13.18.11	30.0/ 51.0	40.6/121.0	3.9	2.7	2.9	-	-	N	N (17)
IRA*196*17NL	07/14	17.49.13	30.0/ 51.0	40.6/121.0	3.4	-	2.8	-	138	N	N (17)
RYU*196*18NL	07/14	18.50.33	30.0/132.0	77.4/ 49.4	3.9	3.10	-	-	-	N	L (17)
KRG*197*00NL	07/15	00.35.52	43.0/ 78.0	42.8/ 82.9	3.8	2.9	-	60	-	N	N (17)
RYU*197*02NL	07/15	02.15.42	24.2/125.1	79.9/ 57.7	5.1	4.6	4.3	49	36	29	P (17)
KUR*197*09NL	07/15	09.51.51	47.0/152.0	67.7/ 27.6	4.4	-	-	-	-	N	L (17)
KAM*197*13NL	07/15	13.50.04	53.0/157.0	63.0/ 22.1	3.7	2.90	-	-	-	N	L (15)
KUR*197*17NL	07/15	17.25.37	46.0/149.0	67.9/ 30.0	3.5	-	-	-	-	N	L (16)
TIB*198*02NL	07/16	02.20.24	32.5/ 95.9	59.7/ 76.8	5.2	4.3	4.6	-	48	N	P (15)
TUR*198*02NL	07/16	02.46.51	38.3/ 43.3	30.2/123.3	4.0	4.4	4.7	511	657	40	P (15)
TIB*198*03NL	07/16	03.40.00	32.6/ 95.8	59.5/ 76.8	4.7	3.8	4.1	-	50	N	P (18)
TAI*198*13NL	07/16	13.48.05	23.7/121.3	78.7/ 61.0	4.6	4.5	4.2	120	48	N	P (18)

TABLE A-1

LIST OF EVENTS USED FOR EVALUATION
(PAGE 15 OF 21)

EVENT NAME	DATE	ORIGIN TIME	LATITUDE N/ LONGITUDE E	DELTA/ AZIMUTH	MB	MS RAY	MS LOVE	AR	AL	Z	NOTES
KAM*198*20NA	07/16	20.04.04	54.4/162.9	62.6/ 17.9	4.2	3.2	-	50	-	N	P (18)
MED*199*03NL	07/17	03.14.05	34.0/ 30.0	29.5/146.6	3.9	2.7	3.0	86	147	N	L (19)
KAM*199*08NL	07/17	08.28.52	55.0/159.6	51.5/ 19.8	5.3	4.2	4.2	40	34	N	P (18)
KAM*199*11NL	07/17	11.11.46	57.0/162.0	60.0/ 17.7	3.3	-	-	-	-	N	L (18)
MED*199*16NL	07/17	16.15.38	35.0/ 22.0	26.8/159.5	3.4	3.0	2.6	300	267	N	N (18)
KAM*199*20NL	07/17	20.50.54	55.1/159.5	61.4/ 19.8	4.5	-	3.0	-	18	N	P (17)
SIN*200*03NL	07/18	03.27.07	39.0/ 77.0	45.3/ 87.4	4.0	2.8	3.1	-	47	N	N (18)
CKZ*200*06NL	07/18	06.04.53	51.0/ 66.0	31.3/ 82.9	3.7	2.6	-	80	-	N	L (15)
CRF*200*13NL	07/18	13.45.48	41.6/ 23.8	20.8/151.9	4.0	2.8	3.1	124	165	N	P (18)
TIB*202*10NL	07/20	10.04.18	28.0/ 91.0	61.1/ 83.7	3.9	-	-	-	-	N	N (11)
CHI*203*16NL	07/21	16.11.33	28.8/102.3	65.6/ 73.9	4.8	4.2	4.1	81	61	N	P (16)
WRS*204*05NL	07/22	05.10.40	44.9/ 36.9	22.1/124.3	4.6	4.1	3.7	380	187	N	P (18)
TIB*204*16NL	07/22	16.41.04	31.4/ 91.5	58.5/ 81.1	5.5	5.3	6.1	211	714	N	P (17)
TIB*204*21NL	07/22	21.00.09	31.4/ 91.4	58.4/ 81.2	4.7	3.1	3.8	-	27	N	P (17)
MED*205*18NL	07/23	18.17.25	33.0/ 24.0	29.1/157.0	3.9	2.8	2.6	87	61	N	L (17)
TIB*205*23NL	07/23	23.41.55	31.0/ 91.0	58.6/ 91.8	3.6	-	3.5	-	193	N	N (16)
TUR*206*10NL	07/24	10.22.23	39.4/ 40.1	28.0/126.6	4.4	3.1	3.5	110	115	N	P (15)
KAM*206*13NL	07/24	13.09.26	58.0/162.0	59.0/ 17.4	4.0	3.3	-	94	-	N	L (13)
TIB*206*14NL	07/24	14.58.14	35.8/ 80.6	49.6/ 87.0	4.8	3.5	3.6	14	17	N	P (14)
CAU*208*18NL	07/26	18.57.25	40.0/ 47.0	30.4/116.7	4.0	3.2	3.3	119	96	N	N (13)
KUR*209*00NL	07/27	00.20.55	50.0/159.1	66.2/ 21.7	5.1	4.6	4.6	119	101	N	P (16)
RYU*209*16NL	07/27	16.41.30	25.4/130.5	91.0/ 52.7	5.1	4.5	4.9	67	133	N	P (15)
AFG*211*17NL	07/29	17.10.35	32.0/ 68.0	46.6/101.4	3.8	3.6	3.4	201	231	N	N (20)
KUR*211*21NL	07/29	21.07.16	49.2/156.2	66.5/ 23.9	4.9	4.1	3.9	52	46	N	P (19)
KAM*213*06NL	07/31	06.40.28	56.2/162.9	60.9/ 17.4	4.8	3.6	3.6	36	22	N	P (19)

TABLE A-1

LIST OF EVENTS USED FOR EVALUATION
(PAGE 16 OF 21)

EVENT NAME	DATE	ORIGIN TIME	LATITUDE N/ LONGITUDE E	DELTA/ AZIMUTH	MB	MS RAY	MS LOVE	AR	AL	Z	NOTES
IRA*213*21NL	07/31	21.01.25	31.0/ 52.0	40.1/119.0	3.6	2.7	-	-	-	N	N (19)
KRG*215*10NL	08/02	10.52.27	39.0/ 73.0	43.4/ 90.9	3.7	-	-	-	-	N	N (15)
AFG*215*12NL	08/02	12.56.19	36.0/ 72.0	45.3/ 94.4	3.8	2.7	2.7	127	112	N	N (15)
CYP*215*15NL	08/02	15.11.59	35.0/ 35.0	30.1/138.1	4.5	3.2	3.8	58	212	N	L (18)
TUR*216*02NL	08/03	02.04.26	37.8/ 32.5	26.7/139.7	4.3	3.4	3.9	129	348	28	P (16)
KUR*216*02NL	08/03	02.25.23	46.9/152.6	67.9/ 27.2	4.5	3.4	3.3	35	17	N	P (16)
KAM*216*03NA	08/03	03.57.16	56.0/162.0	61.0/ 19.0	4.0	3.0	3.1	56	61	N	L (17)
KAM*216*12NL	08/03	12.36.47	59.5/163.2	57.8/ 16.2	5.3	4.4	4.3	92	47	N	P (18)
TUR*216*21NL	08/03	21.39.26	37.7/ 32.7	26.9/139.4	4.5	3.9	4.4	262	786	41	P (19)
IRA*216*22NL	08/03	22.47.46	28.2/ 57.0	44.7/115.5	4.8	3.6	3.2	29	18	62	P (18)
RYU*216*22NL	08/03	22.57.22	28.0/133.0	79.6/ 49.5	4.0	-	-	-	-	N	N (19)
KUR*217*04NL	08/04	04.30.30	47.0/151.0	67.4/ 28.3	4.0	-	-	-	-	N	L (16)
TUR*217*05NL	08/04	05.30.00	37.9/ 32.9	26.8/138.9	4.3	3.3	3.8	119	290	N	P (19)
IRA*217*09NL	08/04	09.19.21	28.0/ 57.0	44.9/115.7	4.0	3.3	2.9	87	74	N	N (18)
KUR*217*17NL	08/04	17.51.13	49.2/156.1	66.4/ 24.0	5.7	6.3	6.1	544	67	54	P (20)
KUR*218*00NL	08/05	00.49.03	49.0/157.0	66.9/ 23.4	3.8	-	-	-	-	N	L (20)
MED*219*03NL	08/06	03.45.07	34.0/ 29.0	29.3/148.2	4.0	3.0	3.0	152	95	N	L (16)
IRA*219*07NL	08/06	07.00.56	31.8/ 50.1	38.6/120.6	5.0	4.0	3.7	66	54	37	P (17)
DOD*219*10NL	08/06	10.08.59	36.0/ 27.0	26.9/150.2	4.0	3.1	3.1	145	160	N	L (18)
KOM*219*14NL	08/06	14.17.30	55.0/164.0	62.2/ 17.0	3.7	-	-	-	-	N	L (13)
TUR*220*05NL	08/07	05.42.48	38.0/ 32.0	26.4/140.3	4.0	2.8	3.2	68	179	N	L (14)
IRA*221*19NL	08/08	19.09.34	25.0/ 61.1	49.3/113.3	5.5	4.3	4.3	-	-	41	P (14)
KUR*222*10NL	08/09	10.34.54	49.0/153.0	64.0/ 26.2	4.1	-	-	-	-	N	L (10)
BAI*222*19NL	08/09	19.42.17	53.0/107.5	48.4/ 53.1	5.1	5.0	4.3	147	30	N	P (13)
ERS*222*20NL	08/09	20.51.51	56.8/127.2	52.2/ 38.4	4.8	4.0	4.2	113	112	36	P (17)

TABLE A-1

LIST OF EVENTS USED FOR EVALUATION
(PAGE 17 OF 21)

EVENT NAME	DATE	ORIGIN TIME	LATITUDE N/ LONGITUDE E	DELTA/ AZIMUTH	MB	MS RAY	MS LOVE	AR	AL	Z	NOTES
KUR*222*21NL	08/09	21.09.10	47.0/153.0	67.9/ 26.9	4.1	-	-	-	-	N	L (16)
HNK*223*01NL	08/10	01.05.40	36.0/ 67.0	42.9/ 99.1	4.5	3.2	3.3	46	17	N	L (15)
YUG*225*23PE	08/12	23.47.57	41.1/ 22.7	21.0/154.5	4.4*	3.5	4.0	403	621	12	P (17)
CHI*226*02NL	08/13	02.16.28	33.0/ 93.0	57.9/ 78.8	4.1	3.5	3.7	54	91	N	N (18)
AFG*226*09NL	08/13	09.04.48	36.9/ 71.4	44.3/ 94.2	4.7	3.0	3.0	13	11	N	P (16)
KUR*226*11NL	08/13	11.32.30	49.0/154.0	66.2/ 25.5	3.6	3.3	3.1	161	136	N	L (19)
KAM*226*18NL	08/13	18.21.56	54.0/160.0	62.6/ 19.9	3.6	-	-	-	-	N	L (15)
KUR*228*22NL	08/15	22.51.37	47.0/151.0	67.4/ 28.3	4.1	-	-	-	-	N	L (15)
KAM*229*01NL	08/16	01.44.47	55.0/164.0	62.2/ 17.0	3.4	-	-	-	-	N	L (14)
EKZ*229*03NA	08/16	03.16.57	49.8/ 78.1	37.9/ 75.5	5.2	3.1	-	5.0	-	O	PY(15)
IRA*229*05NL	08/16	05.42.23	36.0/ 49.0	34.6/118.4	3.5	3.0	3.0	326	369	N	N (13)
KOM*229*08NL	08/16	08.21.14	55.0/164.0	62.2/ 17.0	3.6	2.9C	-	-	-	N	L (14)
AFG*229*10NL	08/16	10.15.32	38.0/ 71.0	43.2/ 93.6	3.6	-	2.8C	-	222	N	N (14)
KOM*229*10NL	08/16	10.26.58	55.0/165.5	62.4/ 16.1	4.3	3.0	-	38	-	N	P (14)
KUR*229*19NL	08/16	19.27.10	45.0/149.0	68.8/ 30.4	4.5	3.3	3.2	25	22	N	L (14)
KAM*229*21NL	08/16	21.37.19	56.0/163.0	61.1/ 17.4	3.6	-	-	-	-	N	L (13)
GRE*231*08NL	08/18	08.10.18	40.0/ 22.0	21.9/156.7	3.6	3.0	3.2	572	463	N	L (16)
PAK*231*10NL	08/18	10.03.07	25.0/ 64.0	50.6/110.4	3.9	3.8	3.6	370	350	N	N (14)
RYU*231*18NL	08/18	18.42.19	23.8/126.6	80.9/ 56.6	4.8	3.8	4.1	25	32	N	P (16)
KAM*231*19NL	08/18	19.02.01	53.0/159.9	63.5/ 20.3	5.1	3.6	3.6	17	19	N	P (17)
KUR*231*21NL	08/18	21.23.12	50.0/153.0	65.0/ 25.8	5.1	3.6	3.5	15	9.1	N	L (14)
GRE*232*06NL	08/19	06.46.56	38.0/ 23.0	24.1/156.1	3.6	2.6	2.9	216	247	N	L (16)
KUR*232*17NA	08/19	17.54.24	43.2/146.8	70.0/ 32.7	4.3	3.6	3.6	18	21	N	P (13)
KUR*232*21NL	08/19	21.56.10	45.0/149.0	68.8/ 30.4	3.5	-	-	-	-	N	L (18)
KUR*232*23NL	08/19	23.20.48	43.5/148.4	70.1/ 31.4	4.9	4.3	4.4	66	92	39	P (18)

TABLE A-1

LIST OF EVENTS USED FOR EVALUATION
(PAGE 18 OF 21)

EVENT NAME	DATE	ORIGIN TIME	LATITUDE N/ LONGITUDE E	DELTA/ AZIMUTH	MB	MS RAY	MS LOVE	AR	AL	Z	NOTES
WKZ*233*02NZ	08/20	02.59.58	49.5/ 48.2	23.7/101.6	5.7	3.1	2.8	2.7	1.5	0	PX(18)
KAM*233*08NL	08/20	08.10.08	51.3/161.6	65.4/ 19.7	5.2	4.2	4.4	39	43	N	P (18)
KAM*234*10NL	08/21	10.15.44	55.7/161.3	61.1/ 18.5	4.5	-	-	-	-	N	P (18)
KUR*234*13NL	08/21	13.45.49	47.0/151.0	57.4/ 28.3	4.0	-	-	-	-	N	L (16)
SIK*234*14NL	08/21	14.04.34	27.2/ 88.0	60.3/ 86.7	4.8	4.0	4.0	49	61	N	P (16)
SIK*234*18NA	08/21	18.55.07	27.2/ 88.0	60.3/ 86.7	4.5*	3.4	3.4	28	29	N	P (14)
CRE*235*02NL	08/22	02.44.10	35.0/ 25.0	27.4/154.3	4.0	2.5	2.6	67	91	N	L (18)
KUR*235*03NL	08/22	03.37.00	47.0/153.0	67.9/ 26.9	4.1	3.10	-	25	-	N	L (18)
SIN*235*16NL	08/22	16.34.56	40.0/ 79.0	45.5/ 84.9	4.6	3.0	3.3	12	16	N	L (15)
TAI*235*21NL	08/22	21.54.53	23.0/121.0	79.2/ 61.6	4.2	-	4.5	-	379	N	N (15)
KUR*236*10NL	08/23	10.38.08	49.0/156.0	66.6/ 24.1	3.7	3.0	3.0	86	86	N	L (13)
TUR*236*21NL	08/23	21.14.16	39.0/ 29.0	24.6/144.5	4.0	2.4	2.7	60	76	N	L (17)
KAM*237*17NL	08/24	17.05.56	53.0/160.0	63.5/ 20.2	3.8	-	-	-	-	N	L (14)
KUR*237*22NL	08/24	22.54.19	48.0/147.0	65.5/ 30.6	3.8	-	-	-	-	N	L (15)
SIB*238*04NL	08/25	04.11.20	71.0/138.0	43.1/ 22.3	4.0	2.5	2.4	28	37	N	L (13)
TUR*240*01NL	08/27	01.14.57	38.0/ 30.0	25.8/143.6	3.6	-	-	-	-	N	N (18)
BUR*240*14NL	08/27	14.42.46	23.0/102.0	70.6/ 77.4	4.0	-	-	-	-	N	N (17)
BUR*240*14N1	08/27	14.49.32	22.6/100.7	70.3/ 78.7	4.8	4.9	5.0	-	-	N	P (18)
HNK*240*16NL	08/27	16.54.01	36.0/ 70.0	44.3/ 96.3	3.6	2.7	2.7	116	77	N	N (16)
KUR*241*09NL	08/28	09.00.22	49.0/155.0	66.4/ 24.8	3.7	-	-	-	-	N	L (19)
MED*242*21NL	08/29	21.59.23	33.0/ 27.0	29.8/152.0	4.4	3.4	3.4	99	59	N	L (16)
CRE*242*22NL	08/29	22.17.52	36.0/ 26.0	26.6/151.9	3.6	2.7	2.7	359	225	N	N (17)
TIB*242*23NL	08/29	23.00.21	34.0/ 82.0	51.8/ 87.2	3.7	3.1	3.2	138	151	N	N (17)
YUG*243*00NL	08/30	00.08.23	44.0/ 16.2	17.1/166.9	4.3*	2.0	2.7	28	48	N	P (17)
CHI*243*15NL	08/30	15.14.10	36.7/ 96.5	56.5/ 73.4	5.5	5.1	5.0	92	105	N	P (19)

TABLE A-1

LIST OF EVENTS USED FOR EVALUATION
(PAGE 19 OF 21)

EVENT NAME	DATE	ORIGIN TIME	LATITUDE N/ LONGITUDE E	DELTA/ AZIMUTH	MB	MS RAY	MS LOVE	AR	AL	Z	NOTES
SIN*243*17NL	08/30	17.52.23	40.0/ 94.0	52.7/ 73.0	4.2	3.5	3.1	38	34	N	N (18)
CRS*244*14NL	08/31	14.03.16	52.3/ 95.4	44.0/ 61.2	5.5	4.6	5.0	78	87	N	P (17)
MON*244*17NL	08/31	17.22.47	49.0/106.0	50.9/ 57.3	3.7	-	3.0	-	108	N	L (16)
KAM*244*18NL	08/31	18.12.08	55.0/163.0	62.1/ 17.7	3.5	-	-	-	-	N	L (17)
EKZ*246*08NL	09/02	08.56.58	50.0/ 77.7	37.6/ 75.6	5.1	-	-	-	-	0	PX(19)
SWR*277*08NL	10/03	08.59.58	46.8/ 45.0	24.1/110.0	5.8	2.9	2.7	1.3	1.1	0	PX(16)
UZB*306*04NL	11/01	04.06.45	38.5/ 65.2	40.0/ 98.5	4.4	2.8	2.5	23	-	17	P (20)
HON*306*06NL	11/01	06.22.29	36.7/141.4	74.4/ 39.3	4.4	4.0	3.7	116	88	50	P (20)
KUR*306*16NL	11/01	16.39.51	43.4/146.3	69.6/ 33.0	4.8	4.2	4.1	84	89	48	P (19)
EKZ*307*01NL	11/02	01.26.58	49.9/ 78.8	38.2/ 74.9	6.2	3.8	3.7	1.7	1.2	0	PX(21)
SIN*307*12NL	11/02	12.52.23	39.4/ 73.2	43.2/ 90.4	4.3	2.9	3.0	59	61	N	P (21)
AFG*309*23NL	11/03	23.58.09	35.0/ 69.5	44.9/ 97.6	5.5	5.5	5.3	551	244	30	L (20)
AFG*310*14NL	11/05	14.06.59	36.0/ 72.0	45.3/ 94.4	3.8	-	-	-	-	N	N (18)
CRE*310*19NL	11/05	19.25.42	35.1/ 24.9	27.3/154.4	5.2	3.9	3.8	104	65	N	P (20)
CYP*311*07NL	11/06	07.07.10	34.1/ 33.3	30.4/141.4	3.7	-	-	-	-	N	L (20)
CRE*311*09NA	11/06	09.31.56	34.6/ 25.1	27.8/154.3	4.3	2.5	2.6	38	28	N	L (20)
SIK*311*10NL	11/06	10.56.09	27.0/ 88.7	60.8/ 86.3	4.5*	4.1	4.1	155	147	N	P (20)
TDZ*311*12NL	11/06	12.18.30	38.2/ 69.0	42.1/ 95.2	4.1	3.4	3.5	145	174	N	P (21)
KUR*311*16NL	11/06	16.22.20	44.0/148.8	69.7/ 30.9	4.3	3.9	4.1	120	-	40	L (20)
TAI*312*06NL	11/07	06.40.36	22.7/120.7	79.4/ 62.0	5.3*	4.7	4.8	3.3	2.8	22	P (21)
AFG*312*15NN	11/07	15.12.34	37.0/ 73.0	45.0/ 92.7	4.3	-	-	-	-	N	N (20)
KAM*312*18NN	11/07	18.36.29	53.3/160.0	63.2/ 20.1	4.5	-	-	-	-	N	L (21)
CRE*312*22NL	11/07	22.41.33	34.9/ 24.8	27.4/154.7	4.6	-	-	-	-	16	P (20)
KUR*315*18NL	11/10	18.22.39	50.1/154.3	65.2/ 24.9	3.6	-	-	-	-	N	L (18)
ERS*316*13NL	11/11	13.57.23	49.9/129.6	58.9/ 41.3	3.8	3.1	3.3	135	150	N	L (19)

TABLE A-1

LIST OF EVENTS USED FOR EVALUATION
(PAGE 20 OF 21)

EVENT NAME	DATE	ORIGIN TIME	LATITUDE N/ LONGITUDE E	DELTA/ AZIMUTH	MB	MS RAY	MS LOVE	AR	AL	Z	NOTES
SIN*316*14NL	11/11	14.08.58	41.0/ 77.0	43.8/ 85.6	3.8	3.0	3.0	127	144	N	N (19)
KAM*317*02NL	11/12	02.46.34	55.5/162.0	61.4/ 18.2	4.8	4.6	4.8	275	396	39	P (21)
KUR*318*01NL	11/12	01.56.51	45.7/149.0	68.2/ 30.2	3.7	3.3	3.3	-	181	N	L (19)
IRA*319*18NL	11/14	18.27.04	14.0/ 52.0	55.4/129.2	3.9	3.4	3.3	144	125	N	N (19)
TAI*320*03NL	11/15	03.36.28	22.0/123.0	81.0/ 60.4	4.1	4.5	4.3	289	257	N	N (19)
MED*320*12NA	11/15	12.21.41	32.2/ 28.0	30.8/150.9	4.5	2.9	2.9	28	32	25	L (17)
AFG*320*14NL	11/15	14.56.53	37.0/ 73.0	45.0/ 92.7	3.9	2.6	2.9	-	72	N	N (19)
CRE*321*03NL	11/16	03.13.06	35.0/ 24.0	27.2/156.0	3.8	2.3	-	75	-	N	L (20)
IRA*321*10NL	11/16	10.10.47	34.0/ 46.0	35.0/123.8	3.9	2.8	2.9	77	102	N	N (20)
KUR*322*15NL	11/17	15.58.47	44.0/152.0	70.5/ 28.6	4.0	-	3.4	-	146	N	N (19)
KUR*322*17NL	11/17	17.12.02	44.4/148.6	69.3/ 30.9	3.7	3.3	3.3	292	236	N	L (19)
KUR*323*17NL	11/18	17.53.59	46.4/154.2	68.7/ 26.2	4.0	3.4	3.2	116	108	45	L (22)
CAR*324*07NL	11/19	07.42.01	10.1/ 57.4	61.1/125.3	4.8	4.6	4.0	191	101	N	P (20)
GRE*325*03NL	11/20	03.30.28	39.4/ 21.8	22.5/157.5	4.8*	3.2	3.3	69	61	N	P (20)
IRA*325*03NL	11/20	03.34.34	31.0/ 51.0	39.7/120.2	4.0	3.0	3.2	128	141	N	N (20)
SIN*325*05NL	11/20	05.37.12	43.0/ 84.0	45.6/ 78.2	4.0	3.1	3.8	77	153	N	N (22)
TAI*326*02NA	11/21	02.47.14	23.8/121.6	78.8/ 60.8	5.7	5.9	6.3	222	510	N	P (16)
GRE*329*01NL	11/24	01.35.27	38.8/ 22.3	23.2/156.9	4.3	3.3	3.7	316	448	N	P (19)
GRE*329*03NL	11/24	03.48.38	40.1/ 21.6	21.8/157.5	5.4	4.2	4.2	110	103	N	L (20)
KAM*330*02NL	11/25	02.11.39	52.3/158.9	64.0/ 21.1	3.4	-	-	-	-	N	L (21)
ERS*330*13NL	11/25	13.42.34	56.3/123.3	51.4/ 41.0	5.1	4.4	4.6	95	134	N	P (17)
GRE*330*15NL	11/25	15.20.48	38.4/ 22.3	23.6/157.2	4.0	2.7	2.5	227	100	N	P (20)
IRA*330*22NL	11/25	22.43.30	28.4/ 53.7	43.1/119.0	4.7*	3.8	3.8	104	177	N	P (20)
KAM*331*14NL	11/26	14.52.31	52.1/158.8	64.2/ 21.3	5.2	4.0	4.0	36	22	47	P (22)
ITA*331*16NL	11/26	16.03.12	43.0/ 13.4	17.9/174.0	4.9	3.8	4.5	180	619	N	P (22)

TABLE A-1

LIST OF EVENTS USED FOR EVALUATION
(PAGE 21 OF 21)

EVENT NAME	DATE	ORIGIN TIME	LATITUDE N/ LONGITUDE E	DELTA/ AZIMUTH	MB	MS RAY	MS LOVE	AR	AL	Z	NOTES
WKZ*332*05NL	11/27	05.11.11	52.8/ 62.1	28.3/ 83.1	3.9	2.4	2.5	-	-	N	L (22)
KAM*332*21NL	11/27	21.37.47	53.4/161.3	63.4/ 19.2	4.7	4.0	4.1	121	171	45	P (20)
ARA*333*10NA	11/28	10.19.28	14.8/ 53.8	55.4/126.9	4.8	4.4	4.2	249	159	N	P (19)
MED*333*13NA	11/28	13.26.15	33.8/ 27.9	29.2/150.1	4.8	3.5	3.3	-	-	N	P (19)
KAM*333*18NL	11/28	18.42.47	55.4/162.1	61.6/ 18.1	3.6	-	-	-	-	35	L (18)
MED*334*01NL	11/29	01.57.57	32.2/ 26.5	30.4/153.3	4.4	3.0	-	90	-	N	L (19)
AFG*334*03NL	11/29	03.19.19	36.0/ 72.0	45.3/ 94.4	3.6	-	-	-	-	N	N (21)
AFG*334*16NL	11/29	16.49.36	36.0/ 72.0	45.3/ 94.4	4.1	-	-	-	-	N	N (21)
ARC*335*07NL	11/30	07.34.16	73.3/144.9	42.3/ 17.9	3.6	-	-	-	-	N	L (19)
ITA*335*11NL	11/30	11.25.32	44.1/ 13.0	16.8/174.7	4.4*	3.2	3.1	151	124	N	P (21)
EKZ*345*04NL	12/10	04.26.58	49.8/ 78.1	37.9/ 75.5	5.7	4.0	4.2	9.2	10	0	PX(20)
EKZ-047-05NL	02/16	05.02.58	49.8/ 78.2	38.0/ 75.4	5.6	3.0	3.0	3.8	4.9	0	PX(20)
EKZ-204-01NL	07/23	01.22.58	50.0/ 78.9	38.2/ 74.7	6.3	4.1	3.7	3.4	-	0	PX(17)
CKZ-227-01NL	08/15	01.59.58	42.7/ 67.4	37.9/ 92.2	5.3	3.5	-	-	-	0	PX(10)
CKZ-240-03NL	08/28	03.00.00	52.0/ 69.0	32.2/ 79.2	5.3	2.8	-	2.4	-	0	PX(9)

APPENDIX B

Appendix A does not contain many of the events previously included in the ensemble lists of Special Report No. 5 and No. 7. In Report No. 5, of 152 events listed, only 59 were processed through matched filtering. Several others were used only for measurement of signal loss from beamforming and/or M_s - m_b calculations on the unfiltered data. The remainder of the edited events were not processed. Because of the large number of events which have been fully processed through matched filtering in this contract, only those 59 similarly processed events from 1971 have been included for consistency.

The single event deleted from Special Report No. 7 to the present report was ITA*035*04. This event was reported by seven non-teleseismic stations ($\Delta < 15^{o}$) but only one station assigned an m_b ($m_b = 4.8$). Since the event was not detected at either NORSAR or LASA the value 4.8 was considered erroneous and the event was dropped.

APPENDIX C

This appendix contains the lists of the 93 noise samples edited at NORSAR from 1 May 1971 to 27 March 1973. The data are arranged in the three tables chronologically. Included are the start time, duration, and the number of good sites available.

Table C-1 contains the 25 noise samples edited in 1971. Table C-2 contains the 55 noise samples edited in 1972. Table C-3 contains the 13 noise samples edited in 1973.

TABLE C-1

1971 NORSAR NOISE SAMPLES

Day	Start Time hr:min	Length hr:min:sec	Number of available sites
1 May	18:00	0.39.24	16
15 May	10:00	01.33.52	8
21 May	05:00	01.16.48	14
30 May	13:21	0.57.28	14
13 June	10:00	04.37.20	14
20 June	12:15	01.16.48	14
10 July	23:00	0.51.12	11
20 July	02:00	00.59.44	18
30 July	16:37	01.12.32	15
8 August	20:20	04.24.32	19
19 August	19:50	02.04.44	17
29 August	17:00	02.42.08	15
7 September	20:37	01.55.12	16
13 September	18:00	06.02.40	14
18 September	05:20	03.03.28	16
29 September	17:00	01.50.58	17
8 October	05:20	01.21.04	16
18 October	08:50	0.59.44	16
28 October	00:06	01.38.08	16
6 November	04:00	02.20.48	14
17 November	20:15	04.09.28	20
28 November	06:00	04.03.12	19
6 December	07:45	02.16.32	18
14 December	04:00	02.16.32	15
27 December	20:00	02.29.10	17

TABLE C-2

1972 NORSAR NOISE SAMPLES
(PAGE 1 OF 2)

Day	Start Time hr:min	Length hr:min:sec	Number of available sites
5 January	13:00	6.24.00	14
5 January	19:00	6.24.00	14
9 January	16:30	6.19.44	18
13 January	8:30	3.35.00	13
19 January	4:30	4.45.52	14
30 January	6:00	5.49.52	18
10 February	18:00	4.37.30	19
18 February	5:30	0.21.08	20
26 February	7:30	6.24.00	15
8 March	22:00	2.54.56	16
28 March	22:30	7.06.40	18
8 April	10:30	5.02.56	19
23 April	6:00	4.45.52	22
17 May	5:00	1.25.20	16
27 May	15:00	3.07.44	21
3 June	21:00	4.16.00	17
15 June	17:40	3.35.00	21
7 July	21:00	2.42.08	16
13 July	3:20	2.50.40	20
23 July	14:30	2.29.30	21
1 August	14:15	3.03.28	16
7 August	02:00	06.02.40	22
15 August	11:30	05.02.56	16
18 August	20:00	0.42.40	19
20 August	17:00	07.06.40	21
24 August	22:30	05.02.56	17
28 August	1:00	0.42.40	21
31 August	08:30	05.02.56	18
6 September	10:00	0.42.40	18
9 September	07:00	07.06.40	21
12 September	17:30	06.02.40	17

TABLE C-2

1972 NORSAR NOISE SAMPLES
(PAGE 2 OF 2)

Day	Start Time hr:min	Length hr:min:sec	Number of available sites
14 September	01:10	04.11.44	17
17 September	8:00	0.42.40	19
19 September	10:00	05.02.56	20
24 September	09:00	04.03.12	19
28 September	14:00	0.42.40	19
1 October	14:00	03.33.20	22
6 October	22:00	04.03.12	20
12 October	08:00	04.03.12	19
17 October	10:00	0.42.40	19
18 October	04:00	07.06.40	13
27 October	03:00	04.03.12	18
27 October	22:00	0.42.40	19
4 November	12:00	04.33.04	22
6 November	8:00	0.42.40	20
12 November	21:00	06.06.56	16
15 November	23:00	0.42.40	21
20 November	00:00	03.33.12	18
26 November	20:00	03.33.12	20
4 December	04:00	01.42.24	17
6 December	17:00	0.42.40	21
10 December	15:00	03.33.12	22
18 December	17:30	06.02.40	20
25 December	15:00	03.16.40	21
26 December	15:00	0.42.40	21

TABLE C-3

1973 NORSAR NOISE SAMPLES

Day	Start Time hr:min	Length hr:min:sec	Number of available sites
1 January	08:00	06.33.20	19
8 January	16:00	05.02.56	22
16 January	12:00	06.02.40	16
23 January	19:30	05.02.56	17
31 January	07:00	05.31.52	20
6 February	07:00	03.03.28	19
12 February	06:00	06.02.40	19
20 February	00:00	05.02.56	22
28 February	17:00	04.33.04	15
8 March	02:00	04.11.44	19
14 March	15:00	04.11.44	22
21 March	06:00	07.06.40	22
27 March	21:00	04.03.02	22

APPENDIX D

SOME COMMENTS AND OBSERVATIONS CONCERNING THE EFFECTIVENESS OF THE USE OF LINEAR GROUP VELOCITY CURVES IN CHIRP FILTERING

The chirp matched filters which have been used routinely on NORSAR and ALPA long-period data to enhance signal detectability are designed to have a linear change in frequency within a given passband over a given time interval. At NORSAR, the passband has been 0.025 to 0.059 Hz (17 to 40 seconds) with durations typically from 50 to 1200 seconds. The "best" chirp for an event is the one which produces the maximum increase in peak signal amplitude. Using a linear chirp as a matched filter implies the assumption that the signals being matched have a group velocity which changes almost linearly with frequency. This study compares the actual group velocities of a small set of events with the linear group velocities implied by the best chirps.

The events were six Italian events which occurred on February 4, 5 and 6,1972 in close proximity to one another and which had high signal-to-noise ratio (> 10). Table D-1 gives some epicenter information and Figure D-1 is a map of their locations.

The Love waves of these events are nearly identical; visually the time series overlay one another almost exactly throughout the signal duration. However the Rayleigh wave phases are not as uniform with the two events ITA*035*09NL and ITA*036*07NL having a phase change in the middle of the signal which are not evident on the remaining four. The events were beam-steered to the expected signal arrival azimuth using a velocity of 4.0 km/sec for Love waves and 3.5 km/sec for Rayleigh waves. The bandpass filtering and chirp filter processing were performed on these beamsteered data.

TABLE D-1

EVENT PARAMETERS AND OPTIMUM CHIRP LENGTHS

Name	Δ	Azimuth	EOT	m_b	Optimum Chirp Lengths	
					LR Chirp	LQ Chirp
ITA*035*02NL	17.1	174.1	02.42.19	4.5	85	65
ITA*035*09NL	17.0	174.3	09.18.32	4.4	65	75
ITA*035*17NL	17.1	174.1	17.19.52	4.1	65	75
ITA*036*07NL	17.0	174.0	07.08.13	4.3	105	55
ITA*036*15NL	17.2	173.8	15.14.48	4.2	95	75
ITA*037*01NL	16.9	174.3	01.34.22	4.4	65	65

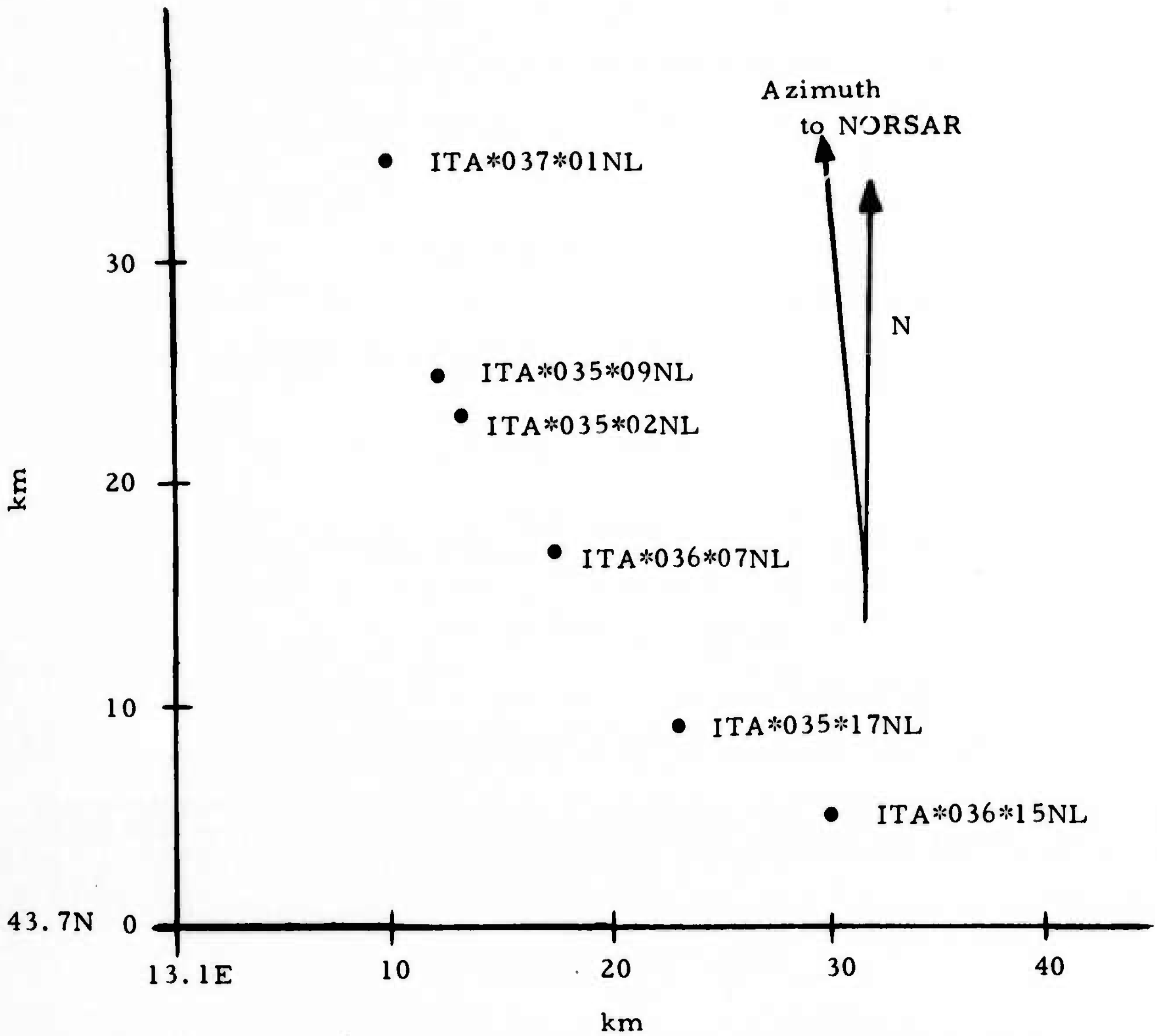

FIGURE D-1

LOCATION OF ITA EVENTS FROM PDE INFORMATION

The highest gain, linear group velocity chirps for these data have been documented in Section V of this report and in Special Report No. 7 and are listed in Table D-1 for both LR vertical and LQ transverse components.

The measurements of the actual group velocity curves were made using the technique of band-pass filtering described Kanamori and Abe, (1968). For both modes, the seismograms were filtered by five zero-phase filters, each having 131 points and using a 2 second sampling interval, which had these pass-bands:

0.020 - 0.030 Hz	centered at 40 second period
0.027 - 0.037 Hz	centered at 30 second period
0.035 - 0.045 Hz	centered at 25 second period
0.045 - 0.055 Hz	centered at 20 second period
0.054 - 0.064 Hz	centered at 17 second period

The time of occurrence of the peak amplitude of the filtered output was taken as the arrival time for the center period of that filter, and from the distance (Δ) listed in Table D-1, the group velocity for the corresponding event and period was computed. These results are plotted by event in Figures D-2 and Figure D-3 for the LR vertical and LQ transverse, respectively.

The maximum amplitudes of the filtered traces were normalized to the 25 second period amplitude for each event and are plotted in Figure D-4. The relative spectral amplitudes shown in Figure D-4 help to explain the large variation in LR group velocities at 17 and 20 second periods shown in Figure D-2. The events with low spectral amplitudes at 17 and 20 seconds are probably contaminated by noise because the noise energy is higher at those periods than at 30 to 40 seconds, thus a large variance of expected arrival times would be expected. High spectral amplitudes for the same filter had peaks within one cycle of one another giving accurate time estimates. Figure D-4 also shows the two different LR wave sets of this suite of events. ITA*035*09NL and ITA*036*07NL

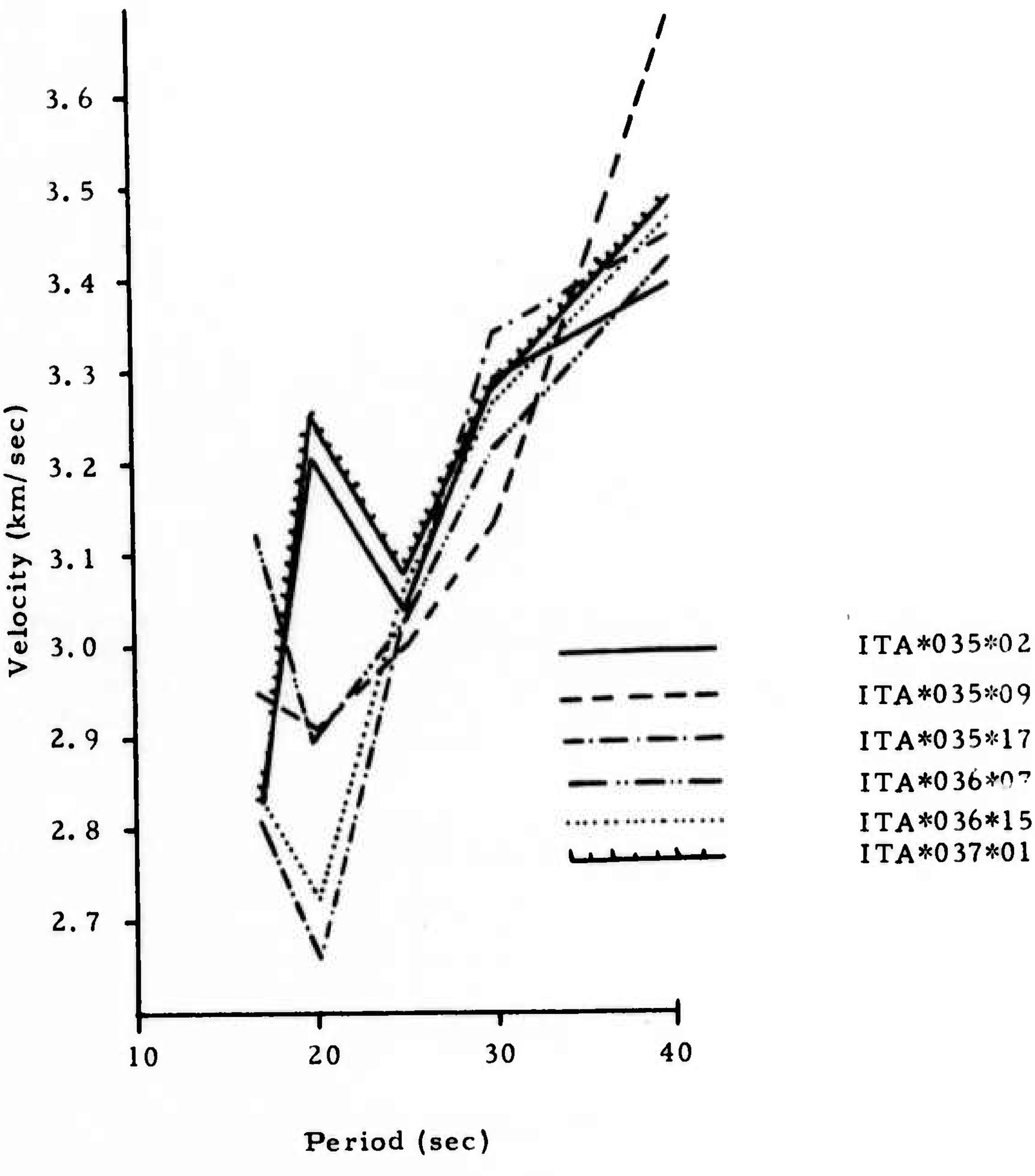

FIGURE D- 2

RAYLEIGH WAVE GROUP VELOCITIES FROM ITALY
MEASURED AT NORSAR

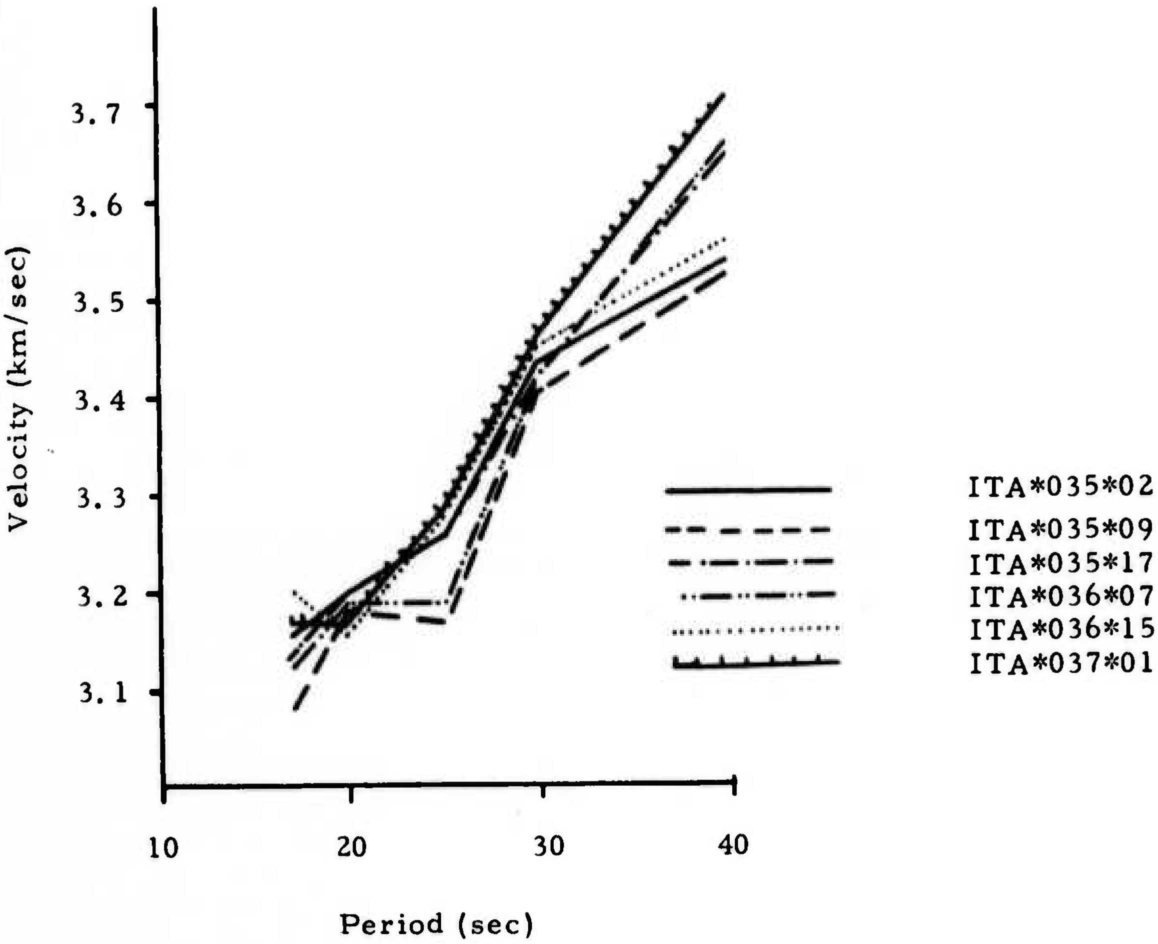

FIGURE D-3

LOVE WAVE GROUP VELOCITIES FROM ITALY
MEASURED AT NORSAR

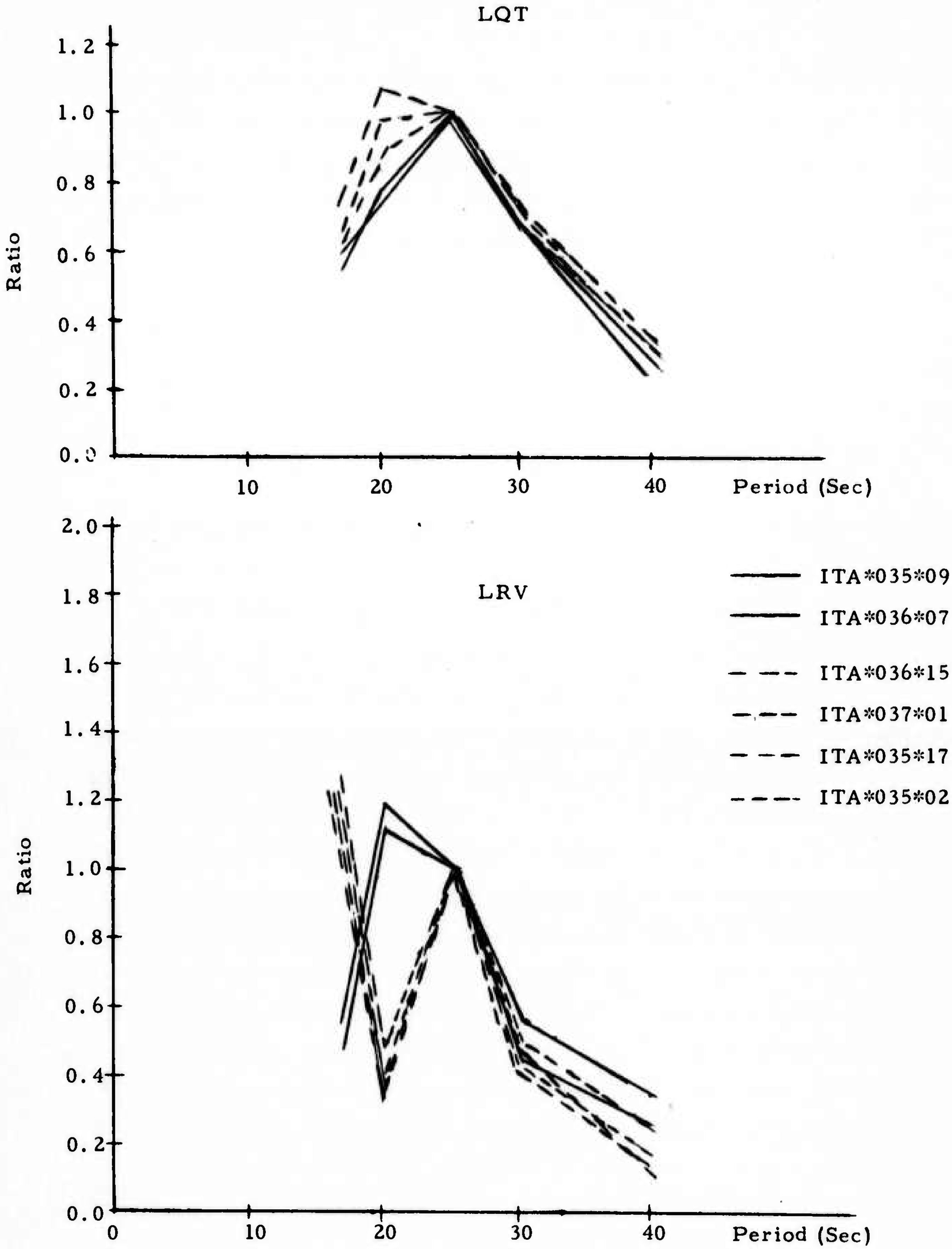

FIGURE D-4

SPECTRAL RATIOS NORMALIZED TO 25 SECONDS

have relatively more 20 second energy and less 17 second energy than the others. LQ relative spectral amplitudes are more consistent between events than the LR data. By omitting the low spectral amplitudes at 17 and 20 seconds on the LR vertical, and taking averages of the remaining at each period, smoothed LR and LQ group velocity curves were obtained and are shown in Figure D-5.

Figure D-6 shows the two group velocity curves of Figure D-5 plotted versus frequency. Also plotted on Figure D-6 are the implied group velocity curves of the chirp filters used when routinely processing the event ITA*035*17NL. The point of intersection on the linear group velocity curves at 0.040 Hz is the zero-phase frequency of the chirp which defines the time at which the chirp filter output maxima should occur. Listed beside each curve is the length of the chirp in seconds. The maximum gain output was for lengths of 75 and 65 seconds for LQ transverse and LR vertical, respectively.

Three things are immediately apparent from Figure D-6. First, the recorded group velocity curves are not linear with frequency over this band. Secondly, none of the chirp filters used in the processing fit the entire curve. Third, the velocity of the chirp maximum at 0.040 Hz does not correspond exactly with the average 0.040 Hz velocity measured with the narrowband filter set. Because the real group velocity is not linear and since the chirps used in the processing are chosen on the basis of maximum gain, then the velocity implied by the chirp should tend to approximate that portion of the real group velocity curve that contains the most energy. For the event used in Figure D-6, the highest spectral amplitudes are at 20 and 25 second periods for the Love wave and at 17 and 25 second periods for the Rayleigh wave. A shift of the linear velocity curves for the chirp of maximum gain (65 seconds for LQ and 75 seconds for LR) to intersect the actual group velocity curves gives nearly exact fits to the actual group velocity curves at the two points of highest spectral amplitude. However, over the range of chirp lengths used on this event,

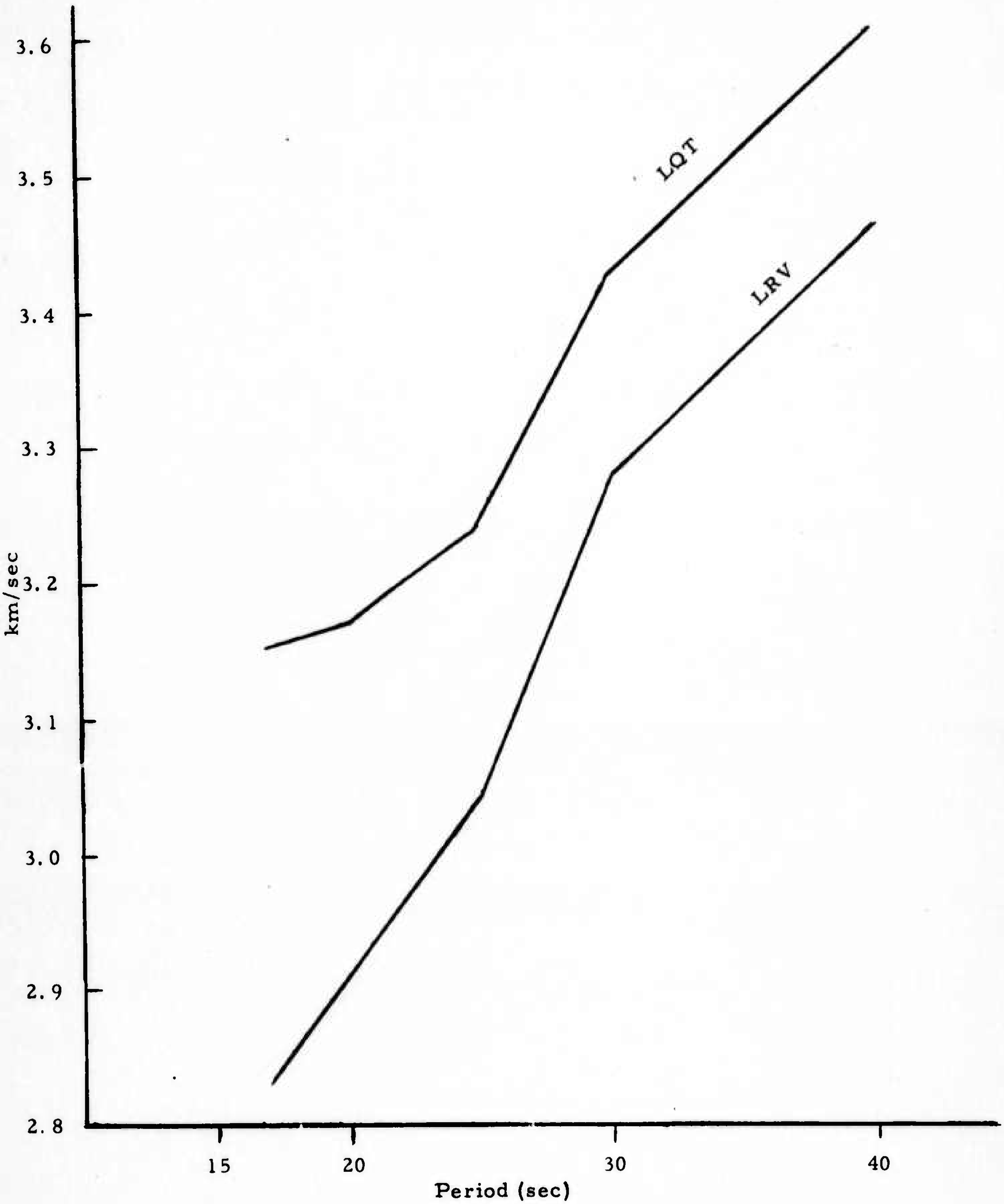

FIGURE D-5

GROUP VELOCITY CURVES FOR ITALIAN EVENTS
AT NORSAR

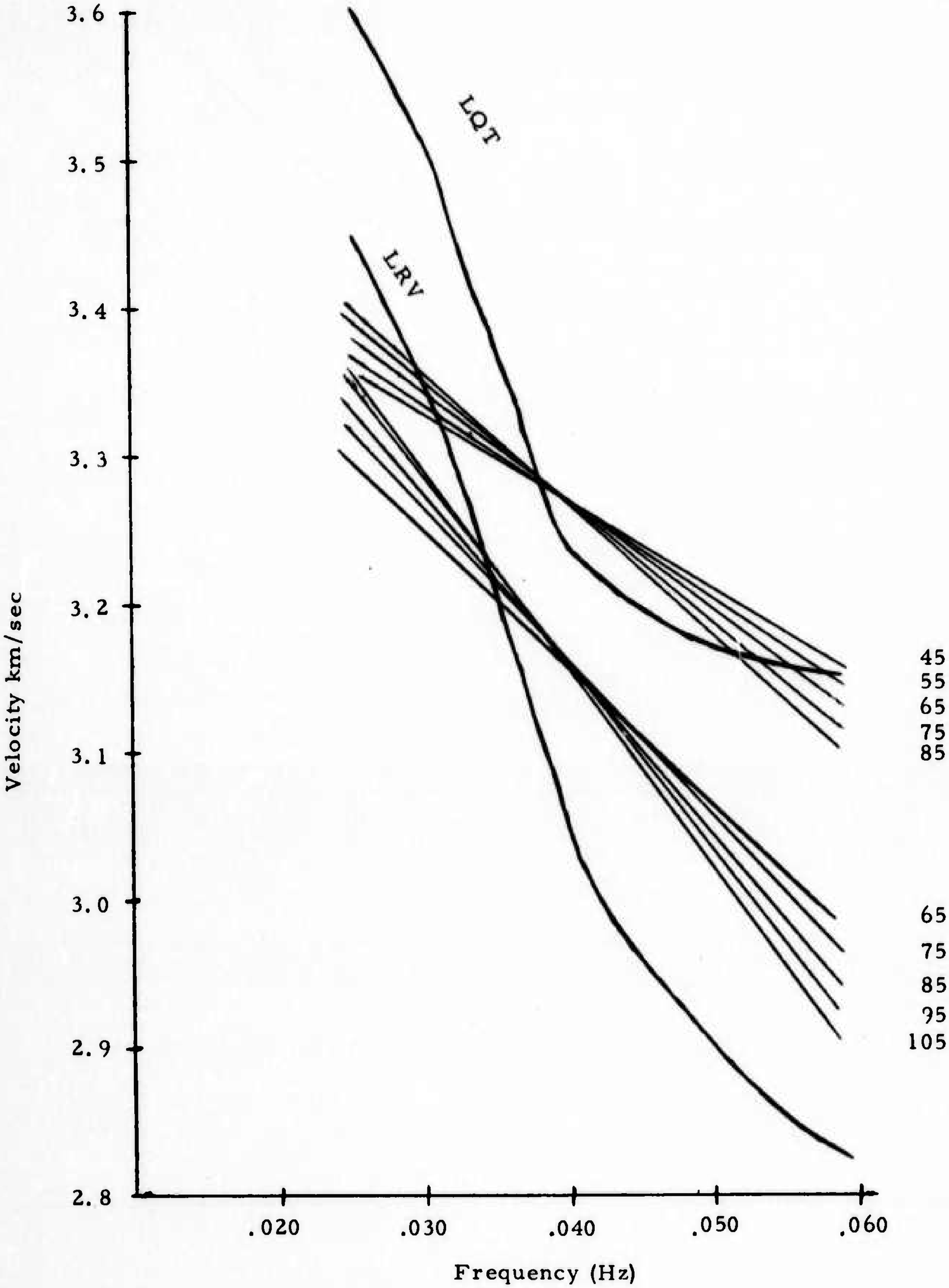

FIGURE D-6

GROUP VELOCITY CURVES FOR ITALIAN EVENTS AT NORSAR

the chirp filter maxima vary by less than 1 percent for the Love mode and less than 10 percent for the Rayleigh mode, so the chirp lengths giving maximum gain are not sharply defined at least for this case.

The arrival time of the chirp peak is also important for detection purposes. The chirp peak should arrive within the same interval that the unfiltered signal should arrive which is (1/2.5 (km/sec)- 1/4.0 (km/sec)) x Δ (km). A non-linear frequency-time chirp that was a better approximation to the dispersed signal would reduce the uncertainty in the arrival time of the zero-phase energy and hence aid detection.

In this report and in Special Report No. 7, the optimum chirp lengths are contoured for the Asian continent for LR and LQ waves. Since it has been shown here that the optimum chirp length is a function of the received signal spectrum as well as the actual group velocity, then some of the questions concerning these plots can be resolved. For example, since the group velocity curve is an average over the entire travel path from source to receiver, the rapid change of chirp lengths around the Hindu-Kush area may be due to signal spectra received at NORSAR rather than extreme velocity changes. Because the actual group velocity curves for Asian events at NORSAR are unknown, the influence of the signal spectra on these chirp lengths also is unknown at present.

The concept of a non-linear chirp filter is similar to that of a reference waveform filter (RWF). Maintaining a file of chirp parameters for various regions would be like maintaining a suite of reference events. The differences, however, are that the chirp parameters would be based on averaged information and would require only minor amounts of storage, and that the resulting chirp would have constant amplitude, precluding the noise sensitivity of RWF's discussed in Special Report No. 7. Thus a non-linear chirp could be expected to produce more gain than a linear chirp, less gain than a RWF, but with greater stability than the RWF.

However, even though chirps and RWF's aid detection by increasing signal-to-noise ratio, these gains are primarily at the 50 percent detection level and not at the 90 percent detection level.